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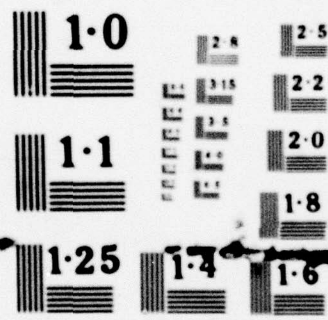
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Final Report

EFFECTIVENESS OF CIVIL DEFENSE SYSTEMS

Prepared for:

Federal Emergency Management Agency
Washington, D.C. 20472

Contract: DCPA01-77-C-0223
Work Unit: 4114H

June 1979

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by

Walmer E. Strope and John F. Devaney

for

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A methodology is presented for assessing the effectiveness of civil defense program elements in reducing nuclear warfare casualties. It consists of two related models of civil defense activities: POPDEF, which assesses fatalities and injuries under nuclear attack, and PAM, which uses data and estimates of the product of specific program elemants to generate most of the inputs to POPDEF. Example results are presented and the use of other measures of effectiveness is discussed.

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DETACHABLE SUMMARY

EFFECTIVENESS OF CIVIL DEFENSE SYSTEMS

Walmer E. Strope and John F. Devaney
Center for Planning and Research, Inc.
Contract No. DCPA01-77-C-0223 June 1979

A methodology has been developed for estimating the individual and combined effectiveness of the important elements of the civil defense operating system and the corresponding elements of the preparedness program, as measured by population survival. All system elements that contribute to the reduction in casualties in a significant way have been incorporated in the analysis and implemented, with the exception of medical care, which could be implemented if the necessary input data were available. The methodology consists of two related models of civil defense activities: the Population Defense Model (POPDEF), which assesses fatalities and injuries under nuclear attack, and the Program Analysis Model (PAM), which uses data and estimates of the product of specific program elements to generate most of the inputs to POPDEF. The use of other measures of effectiveness has been explored.

The Population Defense Model has been implemented at the DCPA Computer Center and used to estimate the casualties associated with three potential civil defense programs under three hypothetical nuclear attacks. POPDEF employs a defense scenario technique to model changes in the vulnerability of the population and to assess casualties. It operates on three regions -- Risk, Host, and Neither -- using data provided by the TENOS model.

The Program Analysis Model identifies relationships among elements of civil defense and defines paths through these relationships along which

quantitative descriptions of the preparedness program can be translated into estimates of the POPDEF input parameters. To provide a structure for PAM, civil defense program elements have been organized and defined. Relationships among these elements are defined by means of a system algebra. The result is a set of system trees in which quantitative estimates of the product of preparedness program elements can be used to generate estimates of key POPDEF input parameters. The two models together allow a detailed program description and changes in any of its elements to be reflected in terms of casualty reduction.

Example calculational results are presented in Table S-1 for three programs and three hypothetical attacks. The programs are Program D Prime, a program that maintains the current civil defense capability, and a program that adds to current capability only a crisis relocation planning effort. Of the three attacks, the first two are major attacks aimed at military and urban-industrial targets. The third, Attack C, is a heavy attack that adds a population-oriented attack against relocation concentrations. The PAM and POPDEF estimates used in these calculations were estimated by the DCPA professional staff.

The exploration of the application of measures of effectiveness other than casualty reduction suggests that the effect is to extend the consideration of countermeasures and hence, the defense scenario into the postattack or recovery period. In lieu of such extension, the analysis concludes that it would be desirable to evaluate candidate civil defense programs on the basis of uninjured survivors and their ratio to the injured.

<u>Recommendations</u>

Based on the work performed under Contract No. DCPA01-77-C-0223, the following recommendations are made:

1. The Population Defense Model (POPDEF) now implemented at the DCPA Computer Center should be adopted as the interim method of casualty assessment for program evaluation and other studies.

2. Research should be undertaken to derive appropriate fatality functions that could be used to represent the effect of various levels of medical care, thus permitting its inclusion in the defense scenario.

3. In program evaluation and design, emphasis should be placed on the number of uninjured survivors and their ratio to the injured rather than on total survivors, so as to maximize the contribution of population preparedness to societal recovery.

4. The Program Analysis Model (PAM) should be reviewed and adopted as the interim method for assessing the contribution of program elements to casualty reduction.

5. The system element structure should be reviewed and adopted as a basis for program analysis in conjunction with the Program Analysis Model. This structure should be considered as a basis for program description and costing.

6. The Program Analysis Model, the Population Defense Model, and the supporting elements of the TENOS model should be considered for use as a tool in defining research needs and data-gathering requirements. Sensitivity analyses should be accomplished in connection with this use to aid in establishing priorities.

7. The methodology should be considered for use in defining the required content of plans and exercises, training, and emergency public information materials, as well as for use in orienting and training civil defense officials in civil defense management and direction and control functions.

8. A formal procedure should be developed for periodic review and upgrading of all aspects of the program evaluation and design methodology.

Table S-1

EXAMPLE ASSESSMENT RESULTS*

Program	Attack A	Attack B	Attack C
D Prime			
Percent Survivors	87%	74%	57%
Percent Uninjured Survivors	80	63	45
Current Capability			
Percent Survivors	52	39	25
Percent Uninjured Survivors	38	25	16
Current Capability Plus Relocation Plans Only			
Percent Survivors	60	46	31
Percent Uninjured Survivors	47%	31%	21%

* All values in terms of percent of the U.S. population.

ABSTRACT

A methodology is presented for assessing the effectiveness of civil defense program elements in reducing nuclear warfare casualties. It consists of two related models of civil defense activities: POPDEF, which assesses fatalities and injuries under nuclear attack, and PAM, which uses data and estimates of the product of specific program elements to generate most of the inputs to POPDEF. Example results are presented and the use of other measures of effectiveness is discussed.

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I. INTRODUCTION

Purpose

The purpose of this report is to document a methodology for estimating the individual and combined contributions of the various elements of a civil defense capability to total system effectiveness, as measured by population survival under nuclear attack. This methodology is an extension of the initial developments reported in Reference 1*. The primary use of the methodology is to aid in the design of civil defense programs intended to maximize effectiveness for a given cost. The method is also useful for estimating the performance of civil defense capabilities, either existing or programmed.

Scope

The work reported here was performed for the Defense Civil Preparedenss Agency under Modification P105-1 to Contract No. DCPA01-77-C-0223, which contained the following scope of work:

> A. General - The Contractor, in consultation and cooperation with with the Government, shall furnish the necessary facilities, personnel, and such other services as may be required to continue the development, based on work accomplished under Contract No. DCPA01-77-C-0223, of techniques for estimating the individual and combined effectiveness of the important elements of the civil defense system and the associated costs thereof. Results shall be compatible with DCPA computational facilities and programs so as to permit DCPA to perform assessments of expected fatalities and injuries, and other measures of effectiveness, in order to improve DCPA's ability to allocate available funds and effort to areas of greatest expected payoff.
>
> B. Specific Work and Services - The Contractor shall perform specific work and services including but not limited to the following:

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* References are listed at the end of the report.

1. Expand the current analysis to include all system elements that contribute to the reduction of casualties in a significant way and improve the basis for quantification of system and element effectiveness to the extent that research and other data permit, performing sensitivity analyses over the ranges of uncertainty that are found to exist. Where the required level of detail results in undue computational complexity, devise appropriate approximations that are computationally efficient.

2. Develop and evaluate alternatives for estimating the performance of individual system elements that are employed in combinations or countermeasures sets in the reduction of casualties. Continue to develop means for assembling the total effectiveness of program elements over the range of preattack and attack environments in which employed, with emphasis on "surge" or crisis-oriented programs. Relate program element costs to effectiveness in casualty reduction for one or more attacks to be specified by the Government.

3. Explore the application of other measures of effectiveness, in addition to casualty reduction, for use in DCPA program allocations. Such measures shall include but not be limited to reduction of long-term and genetic radiation injury, postattack control of disease and disability, maximum postattack availability of the work force, and improvement of industrial and economic recovery rates. Identify those civil defense system elements and corresponding programs that contribute to broader measures of system effectiveness and whose value is only partially measured by their contribution to the reduction of casualties.

4. Recommend an interim system for estimating cost-effectiveness for civil defense program analysis and review and indicate promising avenues of research or operational data gathering that would lead to significant improvement in making such estimates.

The product of research under this scope consists mainly of two related models of civil defense activities: the Population Defense Model (POPDEF), which is the expansion of the original analysis requested in paragraph B.1 of the scope of work, and the Program Analysis Model (PAM), which is responsive to paragraph B.2 of the scope. Additionally, the use of other measures of effectiveness has been explored.

Limitations

The Population Defense Model has been developed to the point where it includes all civil defense elements that contribute significantly to casualty reduction. The "cookie-cutter" version of this model has been programmed for and is operational at the DCPA Computer Center. The simplifications and approximations incorporated in POPDEF appear reasonable. The limitations on the use of this model lie primarily in the quality of the data on which the values of the input parameters are based. In one area, medical care, a basis for estimating fatality reduction is not available.

The Program Analysis Model is the major innovation resulting from the study effort. It required the development of a consistent set of system relations among the basic elements of civil defense. As such, it represents a first attempt at specifying a "fine structure" that could be quantified. Although the authors regard the attempt as highly successful, it is likely that further improvements will be forthcoming as experience is gained in its use and other analysts subject it to scrutiny. A full description of the initial application of the Program Analysis Model will be found in the companion report, Monte Carlo Population Defense Model: Initial Results.[2]

Overview

This introduction is the first of seven sections of the report. Section II provides background information drawn largely from the initial study[1] to lay a basis for understanding of the work reported here. In Section III, the Population Defense Model, the general method used to estimate fatalities and injuries resulting from nuclear attack is described and discussed. The required inputs to the Population Defense Model are generated by use of the

Program Analysis Model, which is presented in Section IV. Example results of the use of these models are presented in Section V, together with a discussion of the potential use of such results in the design and evaluation of civil defense program options.

A discussion of the application of measures of effectiveness other than casualty reduction is presented in Section VI. This section is responsive to paragraph B.3 of the scope of work. Finally, a summary is presented in Section VII, together with recommendations responsive to paragraph B.4 of the scope of work.

II BACKGROUND

Estimates of system costs and effectiveness are input information for the process of developing policies and deciding on the nature and extent of civil defense preparedness programs. In the past, such analyses have been confined, for the most part, to assessing the effectiveness of various kinds of protective shelter under assumed attacks.[3,4] More recently, the efficacy of crisis relocation of urban residents to areas presumed to be at lower risk has been evaluated.[5] Only occasionally have analyses considered explicitly the casualty-reduction potential of warning systems, shelter stocks, and the like. The contributions of other system elements, such as direction and control, training, public information, radiological monitoring and analysis (RADEF), rescue, and fire defense, have not been evaluated although the estimated costs of these and the indirect costs of recruitment, management, and research have generally been included in the system costs assigned to a civil defense posture. Nor has there been a basis other than informed judgment for determining the relative emphasis (and hence, costs) to be assigned to the various system elements to produce a balanced and cost-effective civil defense program option.

To reduce casualties, system elements must operate to reduce the vulnerability of some or all of the population to weapon effects in a quantifiable way. Casualty assessment procedures that relate population vulnerability only to the central countermeasures (sheltering or moving) will hide the contribution of the supporting system elements to casualty reduction. The basic approach used in this and the initial research[1] is to devise a "defense scenario" that traces the changes in population vulnerability and

relates them to the unfolding attack environment, thus bringing hidden contributions to light. It should be noted, however, that defense actions that can influence casualties are usually based on the joint contribution of a number of program elements, such as recruitment, training, organization, equipment, communications, and exercises. Moreover, a particular program element may contribut to several actions in the defense scenario. Hence, a mechanism is required to relate the product of various program elements to the input parameters of the defense scenario so that casualty reduction can be traced back to the contributing program elements. The Program Analysis Model of Section IV has been developed for this purpose. This model uses (a) quantitative estimates of the product of specific program elements and (b) estimates of population response and behavior to build estimates of the input parameters of the defense scenario calculation, now called the Population Defense Model.

The Population Defense Model, in turn, is a specific form of casualty assessment. It is an extension or expansion of the earlier defense scenario model.[1] Since the earlier model, though incomplete, is relatively simple, the essential features that have carried over to the present model will be outlined here as background for the later exposition.

Relationship to TENOS Model

Since any casualty assessment procedure is conditioned to some degree by the nature of the available data bases and associated calculational routines, the defense scenario model has been built on the existing DCPA procedures to the maximum extent possible. The DCPA computer program (TENOS) operates on unit areas defined by two minutes of latitude and longitude over the Continental United States. Each unit area is thus approximately 2 miles (3.2 kilometers) on a side. Unit areas are assigned a resident population based on census data. (The population distribution

in current use represents the 1975 data.) Each unit area also can be identified as being located in a "Risk Area," "Host Area," or "Neither Area." Crisis relocation actions, shelter-use rules, and other program and policy options can be linked to these identifiers.

Most civil defense program options of current interest are based on sheltering all or part of the population in the best available shelter in existing buildings, mines, and tunnels. The data base for this resource is the National Shelter Survey (NSS) inventory. Table 1 describes the all-effects shelter classification used by DCPA. Table 2 indicates the basic protective characteristics attributed to these shelter classes. It will be noted that some classes have been lumped together into categories. In the fourth column, the first number refers to the rated median lethal overpressure (MLOP) and the second number refers to the median casualty overpressure (MCOP). These values represent the midpoints of casualty probability distributions. In the TENOS model, the maximum blast overpressure computed for a unit area is compared with the appropriate casualty function to determine the fraction of the unit area population in a given shelter category who are fatalities or casualties (fatalities plus injuries). Although the computation is referenced to overpressure, the casualty functions consider all prompt effects: blast, thermal radiation, and initial nuclear radiation.

The rated protection factor (PF) against fallout radiation in the last column of Table 2 acts to reduce the free-field radiation exposure, which is calculated as the maximum ERD (equivalent residual dose), a measure that includes the ability of the body to repair some of the injury incurred over a period of time. To determine fallout radiation fatalities, the maximum

Table 1

RELATIVE BLAST PROTECTION CODES*

Preference	Description
A	Subway stations, tunnels, mines, and caves with large volume relative to entrances.
B	Basements and sub-basements of massive (monumental) masonry buildings.
C	Basements and sub-basements of large, fully engineered structures having any floor system over the basement other than wood, concrete flat plate, or band beam support.
D	Basements of wood frame and brick veneer structures including residences.
E	First three stories of buildings with "strong" walls, less than ten aboveground stories, and less than 50% apertures.
F	Fourth through ninth stories of buildings with "strong" walls, less than ten aboveground stories, and less than 50% apertures.
G	Basements and sub-basements of buildings with a flat plate or band beam supported floor system over the basement.
H	First three stories of buildings with "strong" walls, less than ten aboveground stories, and greater than 50% apertures, or first three stories of buildings with "weak" walls and less than ten aboveground stories.
I	All aboveground stories of buildings having ten or more stories. Fourth through ninth stories of buildings having "weak" walls.
NOTE:	For the above description, load bearing walls are considered as "weak" walls.

* Taken from DCPA Attack Environment Manual, Chapter 2, as revised November 1974.

Table 2

DCPA SHELTER CATEGORIES

Category	Shelter Category	Description	Rated MLOP/MCOP	Rated Protection Factor (PF)
1	A	Mines and tunnels	35/25	5,000
2	B/C	Big building basements	10/7	500
3	D	Home basements	10/4	25
4	E/F	Aboveground; strong walls	8/2	55
5	G/H/I	Weak building areas	5/2	70
6	Random	Random residential locations	5/2	10

ERD computed for a unit area is divided by the appropriate PF and the result compared with a casualty function in which the median lethal dose (MLD) is taken to be 375 Roentgens for the blast-injured and 450 R for the uninjured. For radiation injury among those not injured by blast overpressure, the median injury dose is 250 R, whereas combined injury occurs at 200 R.

Another feature of the TENOS model is its ability to "assign" the population to best available shelter according to appropriate priority rules, thus approximating the assignments that would be found in the emergency public information materials (newspaper supplements and video tapes) produced by the Community Shelter Planning (CSP) program element. DCPA practice has been to limit the population of Risk-Area unit areas to shelter available within the same unit area (equivalent to a distance of a mile or less) and to allocate the available shelter in order of its direct-effects protective capability; that is, in the order shown in Table 2. Shelter facilities in the NSS inventory are allocated to the appropriate unit areas and the population is matched against the aggregate spaces available, beginning with Category A. If unsheltered population remains in the unit area after the first two categories are used up, the residual is assigned in part to home basements and in part to lower categories of public shelter, the proportion being the fraction of homes with basements in the State in which the unit area is located. In many unit areas, part of the population will remain unsheltered after the best available shelter is exhausted.

In Host and Neither areas, the assignment is made according to the level of fallout protection (home basements are assigned last) and unit areas are aggregated into 10-minute grids to permit a travel distance of up to five miles (8 kilometers).

A final feature of TENOS that underlies the defense scenario model is the capability to model a people-to-people crisis relocation of Risk-Area population to Host Areas, by either spontaneous or directed evacuation. The population of all Risk unit areas can be multiplied by a reduction factor, and the population of Host unit areas, by an expansion factor to represent the relocation of people.

The Defense Scenario Model

The defense scenario model, as developed in Reference 1, was built on the DCPA casualty assessment procedures described above. It was implemented in two modes, a detailed computer-based version in which the calculations were performed unit-area by unit-area and an approximation version that could be used with a desk calculator. A typical layout of the approximation version is shown in Table 3. A layout of this kind is made for the aggregate of unit areas in Risk, Host, and Neither areas. The layout for Risk areas is shown for a particular civil defense posture and a particular nuclear attack.

The left-hand column contains a series of events in the defense scenario at which an accounting of changes in population vulnerability occurs. The accounting is made at the completion of each event. The column headings indicate the status of the Risk population. Thus, Shelter Assignment is assessed at the completion of the CSP process and shows where the population is planned to be sheltered. Similarly, Warning indicates the status of movement to shelter just before detonations occur.

The decimal fractions in the body of the table represent the fraction of the Risk population in each location. The Shelter Assignment line totals to 1.0 and reflects the aggregate of the matching of population to best

TABLE 3

CASUALTY ASSESSMENT TABLE FOR RISK AREA UNDER PROGRAM B (IN-PLACE)
Fraction or Percent of Population in Various Locations During Emergency
(Population 132,680,723 after 15% Spontaneous Evacuation)

Event	Home Basements		Stay-Puts		In Open	In Public Shelter (Categories A to Y): A		B/C		E/F		G/H/I		X		Y	
	Stay	Move	Stay	Move		Stay	Move	Stay	Move	Stay	Move	Stay	Move	Stay	Move	Stay	Move
Shelter Assignment	.319					.044		.283		.037		.025		.256		.036	
Warning	.319		.068		-0-	.040		.255		.033		.023		.230		.032	
Detonation	.073	(23%)	.004	(6.5)		.026	(65%)	.059	(23%)	.006	(17%)	.002	(9%)	.021	(9%)	.024	(75%)
Fire	.037	(.036)	.002	(.002)		.026		.030	(.029)	.003	(.003)	.001	(.001)	.010	(.011)	.024	
D+1 (R)		.024		.0014					.019		.002		.0007		.007		
(N)		.012		.0007					.010		.001		.0004		.004		
Water	.010	(.027)	.002			-0-	(.026)	-0-	(.030)	-0-	(.003)	-0-	(.001)	-0-	(.010)	.024	
D+2 (R)		.018					.017		.020		.002		.0006		.006		
(N)		.009					.009		.010		.001		.0003		.004		
Emergence		(.010)		(.002)													(.024)
D+14 (R)		.007		.0014													.016
(N)		.003		.0007													.008
Survivors	R	N	R	N		R	N	R	N	R	N	R	N	R	N	R	N
D+1	.017	.004	.0005	.0002		-	-	.019	.005	.002	-	.001	-	.006	.001	-	-
D+2	.013	.004	-	-		.017	.006	.019	.006	.002	-	.001	-	.006	.002	-	-
D+14	.005	.002	.0005	.0002		-	-	-	-	-	-	-	-	-	-	.016	.007
Subtotals	.035	.010	.001	.0004		.017	.006	.038	.011	.004	-	.002	-	.012	.003	.016	.007
Survivors	.045	(14%)	.0014	(2%)		.023	(58%)	.049	(19%)	.004	(13%)	.002	(8%)	.015	(6%)	.023	(73%)

D = Detonation time; D+1 is 1 day after detonation; D+14 is 14 days after.

R = Remedial movement; N = No remedial movement

available shelter in all Risk unit areas. In this connection, it should be noted that the table heading indicates that the program under consideration is being assessed under the assumption of a 15-percent spontaneous evacuation. Thus, the population of each unit area is 85 percent of its resident population. The shelter assignment process using the TENOS model may reflect this somewhat reduced competition for available shelter or it may reflect a CSP based on the original Risk population, under the assumption that the residual population will have the same instructions. (All of the numbers in this table are demonstration values and do not reflect actual program analysis.) It can be seen that in this shelter assignment about 32 percent of the risk population are assigned to home basements. The remaining 68 percent are assigned to public shelter, which includes not only the shelter categories of Table 2 but also two additional kinds of shelter, X and Y, that are peculiar to the program being evaluated. These might be shelters constructed in peacetime, crisis-built expedient shelters, buildings upgraded to provide improved fallout protection, and the like. There is no unassigned population in this shelter posture. If there were, they would be identified as "stay-puts".

At the end of the Warning event, the table indicates that all those assigned to home basements are assumed to be there. Thus, the Assignment and Warning entries in the home basement "stay" column are identical. For those assigned to public shelter, it is assumed that 10 percent are unwarnable or refuse to go to shelter. Thus, 6.8 percent of the Risk population (10 percent of the 68 percent assigned to public shelter) are listed as stay-puts and will be assessed as in Category 6 of Table 2. This assumption also implies that only 61.2 percent of the population actually go to public shelter. Depending on the effectiveness of the warning system, the preparedness of the population to start to move, the distance to the shelters, and the timing of the attack,

some of these people could be caught in the open enroute to shelter. The defense scenario model provides that people in the open be assessed at an MLOP of 2 psi and that the survivors, who would be in the fringes of direct effects, proceed to the assigned shelters for protection against fallout radiation. In Table 3, the Warning line shows that it is estimated that no one is in the open when detonations occur. This estimate would be different under other performance assumptions.

Fatalities due to direct effects are assessed on the Detonation line. The population fractions shown are the survivors. To make these estimates, the TENOS model is called upon to aggregate the results of the attack on each unit area in terms of the distribution of the Risk population with overpressure and ERD. A typical Risk-Area attack environment matrix is shown in Table 4. Values of ERD are the line headings and values of blast overpressure are the column headings. The entries in the table are the percent of the Risk population experiencing less than the stated ERD and *also less than the stated overpressure.* It will be noted that the bottom two lines in Table 4 are identical, indicating that none of the Risk population experiences more than 50,000 ERD (as estimated for an unprotected person). Thus, these lines define the distribution of the Risk population with blast overpressure.

The approximation version of the defense scenario model employs the "cookie-cutter" assumption, which is illustrated in Figure 1. Shown is the DCPA fatality function for shelter categories "B/C" and "D". In the detailed version, this function is used to assess fatalities in each unit area. If the maximum overpressure at the center of a unit area were, say, 5 psi, about 6.5 percent of the shelter occupants would be assessed as fatalities. Half are fatalities at 10 psi; 93.5 percent at 15 psi. The approximation version

TABLE 4

ATTACK ENVIRONMENT MATRIX FOR RISK AREA

ERD	Percent of Population Experiencing Less Than Indicated ERD(r) and Blast Overpressure(psi)										
	2 psi	4	5	7	8	10	14	15	25	35	55 psi
200 r	0.0	0.0	0.0	0.0	0.1%	0.1%	0.1%	0.1%	0.1%	0.2%	0.2%
300	0.0	0.0	0.1%	0.1%	0.1	0.1	0.2	0.2	0.2	0.2	0.3
500	0.0	0.0	0.1	0.2	0.2	0.2	0.2	0.2	0.3	0.3	0.4
750	0.0	0.1%	0.2	0.2	0.3	0.3	0.4	0.4	0.5	0.6	0.7
1000	0.0	0.2	0.3	0.4	0.5	0.6	0.8	0.8	1.0	1.2	1.4
1500	0.0	0.4	0.6	0.8	0,9	1.1	1.5	1.6	2.0	2.4	2.7
2000	0.0	0.6	0.9	1.2	1.4	1.8	2.3	2.6	3.4	3.9	4.5
3000	0.0	1.2	1.7	2.4	2.8	3.5	4.7	5.0	6.6	7.6	8.6
5000	0.0	2.3	3.2	4.7	5.4	6.9	9.7	10.4	14.3	16.3	18.2
7500	0.0	3.4	4.9	7.4	8.6	11.7	16.7	18.0	25.5	29.5	33.2
10000	0.0	4.2	5.9	9.6	11.5	15.3	22.7	24.6	35.8	41.5	46.8
20000	0.0	6.0	8.4	13.6	16.1	21.2	30.5	33.8	49.8	58.7	66.7
50000	0.0	6.5	9.1	14.7	17.4	23.0	34.0	36.7	54.6	65.2	75.2
100000 r	0.0	6.5%	9.1%	14.7%	17.4%	23.0%	34.0%	36.7%	54.6%	65.2%	75.2%

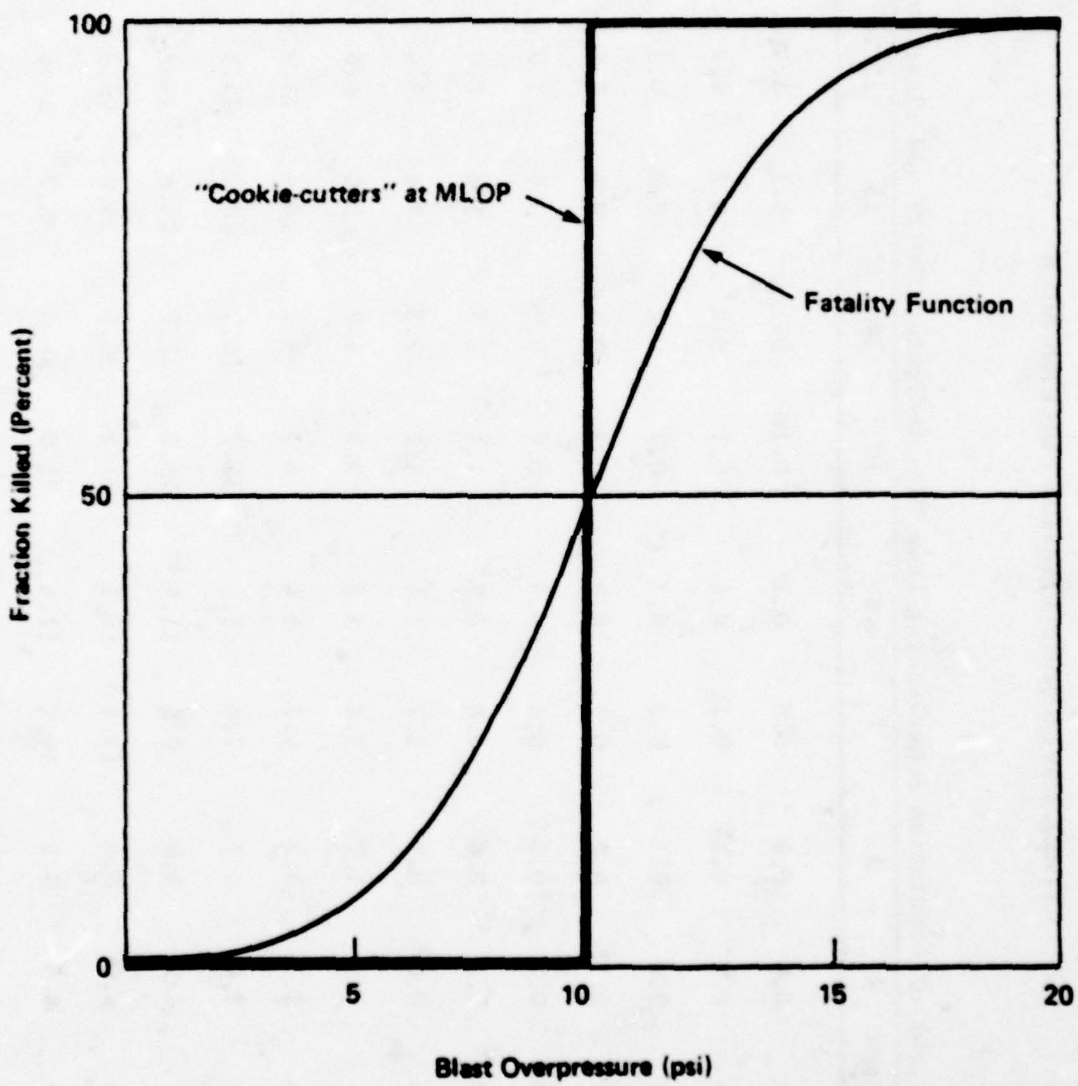

FIGURE 1: FATALITY FUNCTION FOR "B/C" AND "D" SHELTER

uses the heavy vertical line at 10 psi as the fatality function. If the overpressure is less than 10 psi, there are no fatalities. Above 10 psi, there are no survivors. Since the detailed casualty function is symmetrical, this is a very good approximation for large-scale attacks where the population is more-or-less equally distributed over all but very high overpressures.

In Table 4, the bottom line indicates that 23 percent of the Risk population experiences less than 10 psi. This is the percentage survival shown in Table 3 for home basements and B/C shelters. The other estimates are obtained in the same manner.

The next event in the defense scenario concerns the threat of fire in the damaged area following the detonations. Survivors in shelter after the Detonation event can be killed by fires or can be forced to flee from shelters threatened by fire. In this demonstration table, it is assumed that half of the survivors in every shelter category except Category Y are forced from their shelters. (Category Y shelters are single-purpose buried shelters that are fire safe.) Thus, half of the survivors on the Detonation line are shown in parentheses in the "Move" column opposite the Fire event. (The subdivision of this group into R and N fractions is discussed below.) The half remaining in shelter are shown in the Stay column. Since the fractions in the Stay and Move columns add up to the fraction in the Stay column in the previous event, it is seen that no fatalities result from the Fire event. If there had been fatalities, only survivors would be shown in the Stay and Move columns. The effect of the fire event, then, is to force about half of the Risk population out of shelter where they are vulnerable to ensuing fallout. The average time at which this is assumed to occur is shown immediately below the Fire entry as D + 1 or 24 hours after detonation.

Similarly, shelterees can be forced from shelter prematurely by lack of drinking water or an untenable shelter environment. Shown in Table 3 is the event, "Water", in which lack of drinking water forces all of the remaining people from public shelter (except Category Y) at D + 2. In residences (home basements and stay-puts), water is assumed available in hot-water tanks and the like for those survivors experiencing less than 4 psi blast overpressure. Damage is assumed to wreck these sources of water above 4 psi. Thus, at the end of the second day only those shelterees in Category Y shelters, stay-puts, and some survivors in home basements remain sheltered from fallout.

The last event in the defense scenario, "Emergence", is a reminder that survivors cannot remain in shelter forever. In Table 3, emergence is taken arbitrarily to be two weeks after attack. Thus, at the end of the scenario no one remains in shelter. All have moved from shelter as a consequence of either a threat or ultimate emergence.

The calculation of radiation fatalities resulting from the defense scenario depends both on the fallout environment represented by the attack environment matrix of Table 4 and on the effective fallout protection received by the population. The rated protection factors of Table 2 assume an indefinite stay in shelter. The effect of leaving a shelter at a definite time is shown in Figure 2. Here, the upper curves shows the growth of ERD in a decaying fallout field for various times of onset of exposure. For fallout arrival at 1 hour, for example, the dose increases rapidly at first and then levels off as the radiation intensity decreases and some of the injury is repaired by the body. A maximum is reached at about 100 hours after which biological repair exceeds the rate of new injury. For later

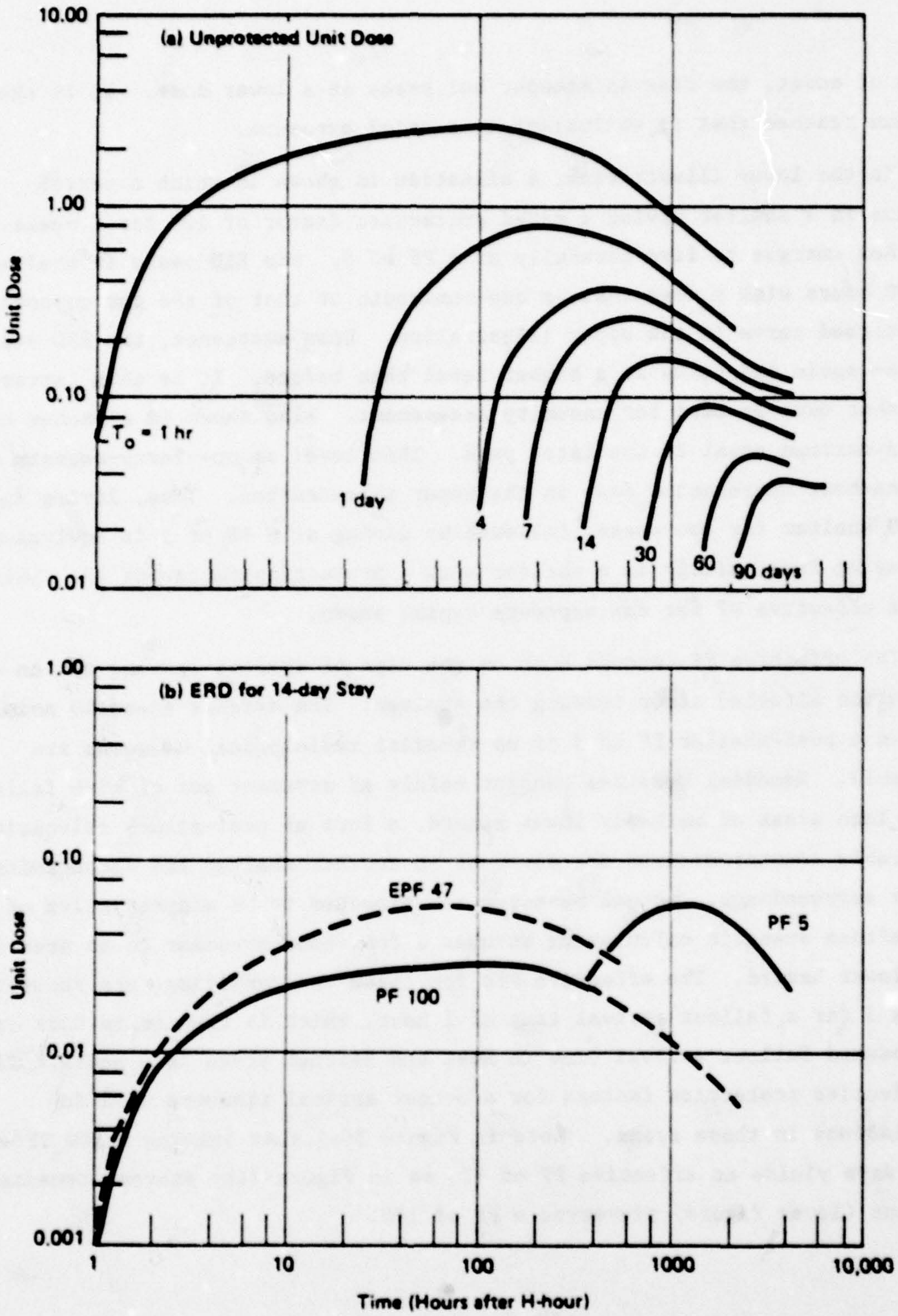

FIGURE 2: EQUIVALENT RESIDUAL DOSE

times of onset, the rise is steeper but peaks at a lower dose. It is the maximum reached that is equivalent to a brief exposure.

In the lower illustration, a situation is shown in which a person remains in a shelter having a rated protection factor of 100 for 2 weeks and then emerges to live carefully at a PF of 5. His ERD peaks in shelter at 100 hours with a dose that is one-hundredth of that of the corresponding unprotected curve in the upper illustration. Upon emergence, the ERD starts to rise again and peaks at a higher level than before. It is this latter peak that must be used for casualty assessment. Also shown is a dashed curve with a maximum equal to the later peak. This level is one-forty-seventh of the one-hour unprotected dose in the upper illustration. Thus, living in a PF 100 shelter for two weeks, followed by living at a PF of 5 is equivalent to staying indefinitely in a shelter with a protection factor of 47. This is the effective PF for the exposure regime shown.

The effective PF depends both on the time of shelter leaving and on the protection afforded after leaving the shelter. The defense scenario model assumes a post-shelter PF of 5 if no remedial radiological measures are available. Remedial measures consist mainly of movement out of high fallout areas into areas of markedly lower hazard, a form of post-attack relocation. Comparable countermeasures are movement to another shelter and decontamination of the surroundings. Actual measures are expected to be a combination of these. The defense scenario calculation assumes a four-hour movement to an area of much lower hazard. The effective PFs for these two conditions are shown in Figure 3 for a fallout arrival time of 1 hour, which is assumed in Risk areas. The assumed fallout arrival time in Host and Neither areas is 5 hours. Tables of effective protection factors for a 5-hour arrival time are used for calculations in these areas. Note in Figure 3(a) that leaving a 100 PF shelter at 14 days yields an effective PF of 47, as in Figure 2(b) whereas remedial movement (lower figure) preserves a PF of 100.

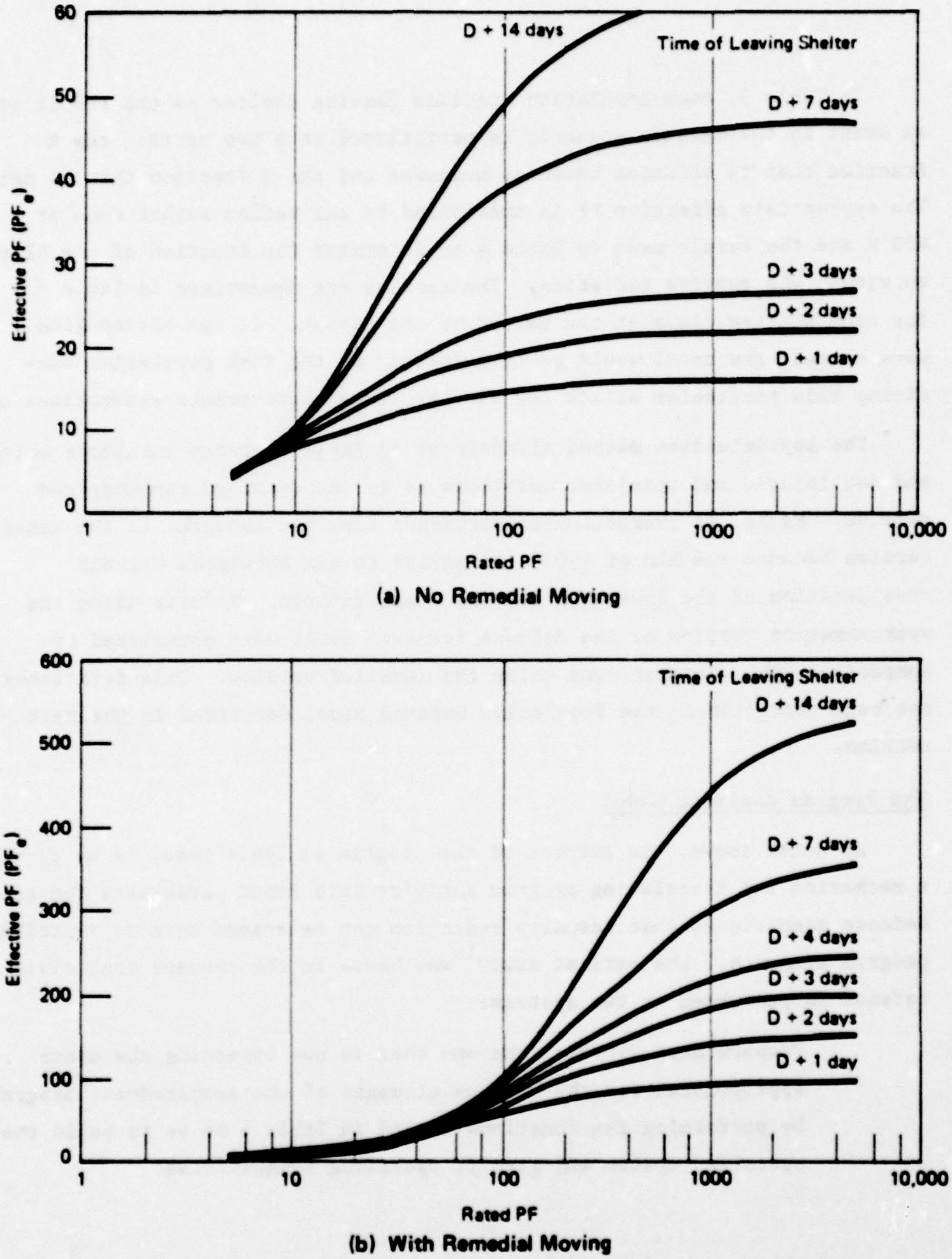

FIGURE 3: EFFECTIVE PF FOR FALLOUT ARRIVAL TIME OF ONE HOUR

In Table 3, each population fraction leaving shelter as the result of an event in the defense scenario is partitioned into two parts: the R fraction that is afforded remedial measures and the N fraction that is not. The appropriate effective PF is multiplied by the median lethal dose of 450 R and the result used in Table 4 to determine the fraction of the blast survivors who survive radiation. The results are summarized in Table 3 for each shelter class at the bottom of the layout. If the bottom line were summed, the total would be 16.2 percent of the Risk population surviving this particular attack for the particular performance assumptions used.

The approximation method illustrated in Table 3 traces survivors only and not injured and uninjured survivors as in the detailed computerized version. Hence, it overestimates survivors somewhat compared to the detailed version because the MLD of 450 R is applied to all survivors without consideration of the lower MLD for the blast injured. Results using the approximation version of the defense scenario model were normalized by comparison with computer runs using the detailed version. This deficiency has been corrected in the Population Defense Model described in the next section.

The Program Analysis Model

As noted above, the purpose of the program analysis model is to provide a mechanism for translating program activity into input parameters for the defense scenario so that casualty reduction can be traced back to contributing program elements. The earlier study[1] was based on the concept that civil defense is performed by two systems:

> Preparedness system: the one that is now incurring the costs appropriated for the various elements of the preparedness program by performing the functions listed in Table 5 so as to build the operating system and give it operating capabilities.

- Operating system: the one that in a nuclear defense emergency would perform those of the activities listed in Table 6 to the extent of system capability so as to achieve reduction in casualties.

Depending on the predominant characteristic of the attack environment at a given time, one function (the central countermeasure) of the operating system would directly achieve a reduction in casualties. Other operating functions (countermeasures) would support the central countermeasure either directly or indirectly. Therefore, each central countermeasure and its supporting countermeasures constitute a set of countermeasures in which:

- The Central Countermeasure performs the function required to reduce casualties in the particular attack environment.
- Primary Support Countermeasures are those that are essential to the performance of the central countermeasure. Inability to support the central countermeasure would seriously degrade its performance.
- Secondary Support Countermeasures are those that support the primary support countermeasures. Inability to do so would seriously degrade the primary support countermeasures.

Identification of these countermeasure sets and definition of the relationships among the countermeasures in them was a major task in the development of the Program Analysis Model (PAM) described in Section IV.

In that task, and in the definition of the relationships between the operating and preparedness systems which was not treated in the earlier study,[1] it was found that some of the theoretical differences drawn in the past caused problems in the practical application. Therefore, the structures of the two systems were modified somewhat to simplify the definition of the relationships between them.

Table 5

PREPAREDNESS SYSTEM FUNCTIONS AND CONTROLS

	Functions	Mission
1.	Developing System	To design and test the total operating system and sets of its elements.
2.	Developing Program	To design and plan an action program for building the operating system.
3.	Providing Facilities	To design, find, identify, construct, improve, maintain, and test structures and other fixed facilities for use in the operating system.
4.	Equipping	To design, procure, distribute, install, maintain, and test non-expendable equipment for use in the operating system.
5.	Supplying	To design, procure, distribute, maintain, and test consumable supplies for use in the operating system.
6.	Developing Operations	To design, plan, and test operations to be performed by the operating system.
7.	Organizing	To (a) assign roles and missions and establish relationships among elements of the operating system; (b) recruit, train, and assign people to staff the operating system; and (c) design and test the procedures to be used in the operating system.
8.	Informing the Public	To inform the public in peacetime and to design and test the materials and methods that the operating system will use for informing the public in the emergency.
	Controls	
1.	Organizing	To (a) recruit, train, and assign staff and (b) provide facilities, equipment, supplies, services, and operating doctrine for the preparedness system.
2.	Planning	To define preparedness system problems and inform the executive of the available courses of action and their probable results and risks.
3.	Informing	To acquire data, process them into the required form, store and retrieve them, and communicate them to the person who needs them when he needs them for use in the functioning of the preparedness system.
4.	Deciding	To form a judgment as to the relative worth of alternative courses of action and to select the one to be taken by the preparedness system.
5.	Commanding	To require that a selected course of action be taken by the preparedness system and to review its effects.

Table 6

OPERATING SYSTEM FUNCTIONS AND CONTROLS

	Functions	Mission
1.	Sheltering	To shield against weapon and attack effects and to provide a viable environment for shelter occupants.
2.	Warning	To alert people and to inform them so that prudent persons will act to bring themselves into the system as intended.
3.	Moving	To move people to where the system can protect or support them and back home when displacement is no longer needed.
4.	Rescuing	To assist people to move from a hazardous place to one of lesser hazard.
5.	Maintaining Health	To minimize the spread of disease.
6.	Fire Fighting	To minimize personal injury and property damage by reducing thermal flux, probability of ignition, and burning rate; and by suppressing fires.
7.	Maintaining Law and Order	To protect people and property against illegal acts and to improve system effectiveness by maintaining order.
8.	Protecting Livestock	To minimize damage to, and denial of the product of, livestock.
9.	Protecting Industry	To minimize damage to, and denial of the product of, industry.
10.	Providing Medical Care	To minimize death and disability from illness and injury and to care for those displaced because of the threat of the attack effects.
11.	Feeding	To provide food and water for those displaced by attack or threat of attack, or for those to whom normal supply channels are closed.
12.	Housing	To provide temporary lodging to people displaced in a strategic or remedial movement.
13.	Restoring Facilities	To repair or replace utilities and facilities vital to the survival of the people and the functioning of the system.
14.	Decontaminating	To minimize denial of access and radiation damage by removing contaminating radioactive materials.
15.	Providing Welfare Services	To provide material aid and counsel for people displaced by attack or threat of attack.

Table 6 (concluded)

OPERATING SYSTEM FUNCTIONS AND CONTROLS

	Controls	Mission
1.	Organizing	To control the employment of available staff, facilities, equipment, and supplies so as to maximize system readiness to use its remaining capability in the real emergency environment.
2.	Planning	To define the problems existing in the situation and to inform the executive concerning the courses of action available to him and the probable results and expected risks for each.
3.	Informing	To acquire data, process them into the required form, store and retrieve them, and communicate them to the persons who need them.
4.	Deciding	To judge the relative worth and desirability of alternative courses of action and to select the course to be taken.
5.	Commanding	To require that a selected course of action be taken and to review the effects of taking it.

III. THE POPULATION DEFENSE MODEL

General

The population defense model (POPDEF) is an evolutionary development of the defense scenario model of the previous report[1] in this series. The objectives of the development have been to expand the model to include all of the activities that contribute to casualty reduction and to improve the basis for estimating performance; that is, effectiveness under nuclear attack. The conceptual analysis applies both to the detailed computations performed unit-area by unit-area and to the approximation model. The necessary expansion of the analysis to accomplish the objectives would make the detailed model a time-consuming program on the DCPA computer and therefore not well-suited to use for program design. Hence, the detailed version has not been implemented. Rather, emphasis has been focused on the approximation model. Earlier comparisons of the results from the detailed and approximation versions of the defense scenario model have provided confidence that the revised population defense model in the approximation form gives reasonably valid results--results that are conditioned primarily by the quality of the input information and only secondarily by the approximations employed.

At the same time, the necessary expansion of the model has removed the approximation model from the category of a desk-top or hand-calculation technique. As a consequence, the approximation version of the population defense model has been implemented on the DCPA computer and is operational. Example results are exhibited in Section V. The essential features of this model (POPDEF) will be described in this section. The computational program is contained in the companion report.[2]

Basic Features

POPDEF operates on three regions -- Risk, Host, and Neither -- using data aggregated from the unit areas by the TENOS model. At present, these are defined on the basis of the DCPA publication TR-82;[6] that is, the Risk region encompasses all of the risk areas defined in TR-82 and the Neither region includes the "green" counties in TR-82. The Host region is the remainder. For each region, TENOS is used to determine the population of the region for a stipulated fraction of the resident population of the Risk region relocated to the Host region (FCR), the distribution of this population with respect to attack effects (overpressure and ERD), and the population assignment to shelter categories, as discussed in Section II.

The model accommodates ten shelter categories, two of which are reserved for those at random in residences (unsheltered, unwarned, stayputs, etc.) and for those in the open at time of detonation. Each shelter category is defined by rated protection characteristics -- MLOP, MCOP, and PF -- that are intended to reflect random location and posture in the shelter area and minimal medical care for the injured. Thus, the maximum number of location columns in an illustrative tableau is one more than the nine shown in Table 3.

A major change introduced in POPDEF is that blast injuries are calculated at the same time as are blast fatalities. Thus, a representational tableau, such as shown in Table 7, has four columns under each location except for those in the open. These are labeled SU and SI for "Stay-Uninjured" and "Stay-Injured" and MU and MI for "Move-Uninjured" and "Move-Injured". This change has been introduced to allow the computation to reflect the greater vulnerability of the blast injured to fallout radiation, as is done in the detailed version. Some general features of the model are shown in Table 7. The first event in the defense scenario is the Shelter Assignment; that is, where it is planned that

TABLE 7
EXAMPLE POPULATION DEFENSE MODEL TABLEAU
(Risk Area With 77% Relocation)

EVENT	HOME BASEMENT STAY SU	HOME BASEMENT STAY SI	HOME BASEMENT MOVE MU	HOME BASEMENT MOVE MI	STAY PUTS STAY SU	STAY PUTS STAY SI	STAY PUTS MOVE MU	STAY PUTS MOVE MI	IN OPEN U	IN OPEN I	SHELTER "A" STAY SU	SHELTER "A" STAY SI	SHELTER "A" MOVE MU	SHELTER "A" MOVE MI
SHELTER ASSIGNMENT	.256				.204				—		.084			
WARNING	.220				.201				.011		.046			
DETONATION	(.070)	(.062)			(.043)	(.047)			(.002)	(.001)	(.030)	(.002)		
a. Not Trapped	.070	.043			.042	.030			.002	.001	.030	.001		
b. Trapped	—	.020			.001	.000			—	—	—	.001		
RESCUE	.070	.042	(—)	(.007)	.042	.030	(.001)	(.000)			.030	.001	(—)	(.001)
H+60(R)			—	.001			—	—					—	—
H+60(N)			—	.006			.001	.000					—	.001
FIRE	.071	.030	(.006)	(.005)	.042	.037	(—)	(.001)			.030	.001		
H+1(R)			—	—			—	—						
H+1(N)			.005	.005			—	.001						
WATER	.060	—	(.007)	(.030)	.042	.037					.030	—	(.020)	(.001)
H+20 (R)			—	.001									.002	—
H+40 (N)			.003	.037									.020	.001
VENTILATION	.060	—			.042	.037							(.000)	(—)
H+01 (R)													.003	—
H+100 (N)													.005	—
EMERGENCE			(.060)	(—)			(.042)	(.037)						
H+100 (R)			.010	—			.022	.001						
H+210 (N)			.060	—			.020	.030						

EVENT	SHELTER "B/C" STAY SU	SHELTER "B/C" STAY SI	SHELTER "B/C" MOVE MU	SHELTER "B/C" MOVE MI	SHELTER "E/F" STAY SU	SHELTER "E/F" STAY SI	SHELTER "E/F" MOVE MU	SHELTER "E/F" MOVE MI	SHELTER "G/H/T" STAY SU	SHELTER "G/H/T" STAY SI	SHELTER "G/H/T" MOVE MU	SHELTER "G/H/T" MOVE MI	SHELTER "X" STAY SU	SHELTER "X" STAY SI	SHELTER "X" MOVE MU	SHELTER "X" MOVE MI
SHELTER ASSIGNMENT	.273				.043				.020				.120			
WARNING	.250				.037				.017				.120			
DETONATION	(.116)	(.026)			(.006)	(.042)			(.003)	(.004)			(.110)	(.003)		
a. Not Trapped	.114	.010			.006	.011			.003	.003			.110	.001		
b. Trapped	.002	.000			—	.001			—	.001			—	.002		
RESCUE	.116	.010	(.001)	(.006)	.007	.011	(—)	(.001)	.003	.003	(—)	(.001)	.110	.001	(—)	(.002)
H+60(R)			—	—			—	—			—	—			—	—
H+60(N)			.001	.006			—	.001			—	.001			—	.002
FIRE	.107	.017	(.000)	(.002)	.007	.010	(—)	(.001)	.003	.003	(—)	(—)	.110	.001		
H+1(R)			—	—			—	—			—	—				
H+1(N)			.060	.002			—	.001			—	—				
WATER	.041	—	(.060)	(.017)	.003	.003	(.004)	(.007)	.001	.001	(.002)	(.002)	.110	.001		
H+20 (R)			.013	—			.002	—			.001	—				
H+40 (N)			.063	.017			.002	.007			.001	.002				
VENTILATION			(.041)	(—)			(.003)	(.003)			(.001)	(.001)	.110	.001		
H+01 (R)			.013	—			.002	—			.001	—				
H+100 (N)			.070	—			.001	.003			—	.001				
EMERGENCE															(.110)	(.001)
H+100 (R)															.016	—
H+210 (N)															.004	.001

the population be sheltered. The entries are in fractions of the Risk population remaining after a major crisis relocation and total to unity. They are drawn from a TENOS allocation that matches people to shelter unit-area by unit-area. The first three main column headings cover those assigned to home basements, those at random in residences (stay-puts), and those in the open at time of attack. The remaining columns cover the public shelter categories. No one is planned to be in the open but, in this example, 20.4 percent of the Risk population have no shelter assignment and are listed as stay-puts.

The next event, Warning, shows the disposition of the population after the Warning process and just prior to weapon detonations. Some people may not have heard or recognized the warning, may be in the process of preparing to move to shelter, or may refuse to take action. This fraction may be specified for each public shelter category and for home basements. The stay-puts are deducted from the assigned fractions and added to the Stay-Put column. *Additionally, some fraction* of those moving to public shelter may be caught in the open at time of detonation. This fraction may be specified for each public shelter class. They are deducted from the planned shelter assignment and placed in the In-Open column. In this example, there are neither stay-puts nor people caught in the open in shelter category "X," which are key-worker shelters in or adjacent to the work place. Hence, the shelter assignment fraction is repeated on the warning line. In other public shelters there are both stay-puts and people caught in the open that reduce the assigned fraction. In home basements, 11 percent have not moved to the basement and are reclassified as stay-puts.

At the Detonation event, fatalities and injuries from direct effects are assessed. The surviving uninjured and injured are shown in parentheses in the Stay column under each location. The sum of uninjured and injured are the total survivors in the location. The entries are in fractions of the total

Risk population and are obtained by entering the appropriate attack environment matrix (similar to Table 4) with the MLOP and MCOP for each location. The fraction of the population experiencing less than the MLOP are classed as survivors and the fraction less the MCOP are uninjured survivors. The underlying assumption is that the population in each shelter class is distributed with respect to attack effects identically with the total population. This assumption has not been tested in detail but appears to be a close approximation based on comparison of the detailed and approximation model results for the earlier defense scenario model.

The detonation survivors are then partitioned into those who are trapped in debris and those who are not. This is accomplished by associating with each location a median trapping overpressure (MTOP). Survivors experiencing less than the MTOP are not trapped. Further, a value is assigned to the fraction of the trapped who are uninjured. This permits the trapped and not-trapped to be defined as uninjured or injured. The sum of trapped and not-trapped in each column must equal the survivors carried in parentheses on the Detonation line. This procedure is necessary so that the Rescue and Fire events can be assessed.

The Rescue event operates only on the trapped survivor fractions. Hence, the entries in the Stay columns are the fraction not trapped. An exception are the survivors of those who were caught in the open. Since the MLOP for this group is usually taken to be either 2 or 3 psi, the survivors are in the lightly-damaged region and are assumed to continue to their assigned public shelter, as indicated by the arrows in the In-Open column. Accordingly, the entries in the public shelter Stay column are somewhat higher than the entries on the Not Trapped line. (Rounding of entries does not always show this. The actual computation always includes the necessary adjustment.)

Those of the trapped who are rescued are shown in the Move column for each location, where they are partitioned into those afforded remedial radiological measures (R) and those who are not (N). These sub-sets sum to the totals in parentheses, which in turn represent the fraction of the trapped who are rescued. Those who are not rescued are assessed as fatalities and drop out of the tableau, which traces the fate of the survivors. The effective time at which rescue occurs (90 hours after detonation in the example) depends on the analysis of the rescue operation, as discussed later.

The Fire event operates on the not-trapped fraction shown in the Stay columns on the Rescue line. Some fraction of these may be forced to abandon the shelter location because of the threat of fire. These are shown in parentheses in the Move columns. In the example shown in Table 7, Shelter categories "A" and "X" are judged not to be at fire risk; hence, the Move columns are blank. On the other hand, shelter category "G/H/I" is subject to fire risk although the population fraction forced to move is so small that it rounds to zero in the table. The small fraction is carried in the actual calculation. The fraction forced out of shelter as well as those remaining in the Stay column can also be reduced to account for fire fatalities. As in the Rescue event, the fraction forced to move is partitioned into (R) and (N) fractions.

The next event in the scenario accounts for those forced prematurely from shelter because of lack of drinking water. The fractions forced to move are related to the availability of stored water and to the effects of damage on the water supply. The effective time at which movement occurs is related to the heat environment in the shelter (as is the subsequent Ventilation event), which in turn is a function of climate and time of year in which the attack occurs. As discussed later, the current analysis results in different

effective times for the (R) and (N) fractions. One aspect of these events is the matter of preattack stocking of water containers and ventilation devices. In the example, only shelter category "X" is assumed to be so stocked. Hence, only occupants of this shelter category, stay-puts, and survivors in home basements in the low overpressure region remain in shelter until final emergence.

As discussed in Section II, each population fraction in the Move columns is accorded an effective protection factor (EPF) against fallout radiation based on the rated protection of the shelter category, the time of shelter-leaving, and availability of remedial radiological measures. The EPF is used in conjunction with the attack environment matrix and the appropriate median lethal dose (MLD) and median sickness dose (MSD) to determine the injured and uninjured survivors from fallout radiation. Note that at the conclusion of the scenario all survivors are in the Move columns.

Three events in the revised defense scenario have been omitted from Table 7 as a matter of convenience. These events, which do not affect the population fractions in the Stay and Move columns, are discussed below.

The Revised Defense Scenario

As an aid in explaining the operation of the Population Defense Model in more detail, Table 8 shows the revised tableau for a single shelter category, the "B/C" category of Table 7. As noted in Table 1, these shelters are in the basements and sub-basements of large buildings. The entries in Table 8 are the same as those in Table 7 for this category except that the entries are in percentages of the Risk population rather than decimal fractions and are carried to one more significant figure for illustrative purposes.

Table 8

EXAMPLE TABLEAU FOR CATEGORY "B/C"

(Risk Area With 77% Relocation)

EVENT	STAY SU	STAY SI	MOVE MU	MOVE MI	INPUTS
Shelter Assignment	29.30				FCR = 0.77; FA = 0.293
Warning	25.01				FS = 0.12; FE = 0.03
Protective Posture (Medical Care)	25.01				ΔMLOP = 0.03; ΔMCOP = 0.03
					ΔPF = 0.75; FPF = 0.05
Detonation	(11.60)	(2.61)			MLOP = 10 psi; MCOP = 7 psi
a. Not Trapped	11.41	1.85			MTOP = 9.1 psi; FTU = 0.20
b. Trapped	0.19	0.76			PF = 500
Rescue	11.53	1.93	(0.14)	(0.57)	FR = 0.75
H + 90 (R)			-	0.01	FRR = 0.02
H + 90 (N)			0.14	0.56	
Fire	10.70	1.72	(0.82)	(0.21)	FF = 0.11; FFR = 0.02
H + 1 (R)			0.02	-	FFSS = 1.0; FFSM = 0.99
H + 1 (N)			0.80	0.21	PSIF = 2 psi
Water	4.08	0.04	(6.62)	(1.68)	FW_1 = 0.50; FW_2 = 1.0
H + 36 (R)			1.33	0.03	PSIFW = 4 psi; PSIW = 2 psi
H + 46 (N)			5.29	1.65	FWR_1 = 0.64; FWR_2 = 0.02
Ventilation			(4.08)	(0.04)	FV = 1.0; PSIV = 2 psi
H + 91 (R)			1.27	-	FVR_1 = 0.82; FVR_2 = 0.02
H + 166 (N)			2.81	0.04	

Since the population in this category are all forced from shelter by the end of the Ventilation event, the Emergence event has been omitted. Also shown in Table 8 are the inputs to the computational program that must be specified, together with example values of the input parameters. The actual calculations are made in terms of population rather than percentages or decimal fractions; hence, the resident population of the Risk, Host, and Neither areas are also an input to the computation. FCR, the fraction of the Risk population that has relocated to the Host area prior to attack, thus defines the population in the Risk Area at time of attack. FCR is taken here to be 77 percent. The value of FCR is calculated by means of the Program Analysis Model described in the next section. The specific procedure for calculating FCR is provided in Appendix B. The fraction of the population assigned to shelter category "B/C" is FA, which is the output of the aggregate of the TENOS shelter assignment process at the unit area level. In this example, as in Table 7, FA is 0.293. Thus, 29.3 percent of the residual population in the Risk area is assigned to this shelter category.

To obtain the fraction of the population actually in this shelter category at time of detonation, two inputs must be specified: FS, the fraction not moving to shelter, and FE, the fraction caught in the open enroute to shelter. These inputs are also generated by the Program Analysis Model as discussed in Section IV and in Appendix B. The example values shown in Table 8 are 0.12 for FS and 0.03 for FE. Thus, the assignment, 29.3 percent, must be multiplied by 0.12 to find that 3.52 percent of the population are stay-puts at time of attack. The remainder, 25.78 percent of the population, move to shelter. Of these, 3 percent are caught enroute, leaving 25.01 percent in shelter category "B/C" at time of attack.

The Protective Posture event is now introduced into the scenario. This activity does not change the amount of population in shelter but it changes the vulnerability of this population to attack effects. The rated protection

characteristics of the "B/C" shelter category (MLOP, MCOP, PF, and the casualty functions on which they are based) assume random location and posture (standing, sitting, or lying down). If, for example, shelter managers were to seat shelterees along the walls and around columns away from the center of ceiling spans, both fatalities and injuries would be reduced. This defense action is accounted for in the computation by means of the inputs ΔMLOP and ΔMCOP. Estimates of these parameters are obtained in two steps: first "technical" estimates are made of the fractional increase in MLOP and MCOP if everyone were in the protective posture. This potential increase is then multiplied by an estimate of the fraction of the shelter population actually in the protective posture to obtain the net ΔMLOP and ΔMCOP. The procedure for making these estimates by means of the Program Analysis Model is given in Appendix B. In this example, both ΔMLOP and ΔMCOP are assessed at 3 percent. This means that the survivors on the Detonation line will be assessed by entering the attack environment matrix with an MLOP of 10.3 psi rather than 10.0 psi and an MCOP of 7.2 psi rather than 7 psi. This procedure is satisfactory because the distribution of population with overpressure is uniform in the region of interest for large attacks.

Similarly, the rated PF of a shelter is based on random location and posture. If, after fallout arrival, a shelter monitor or manager is able to locate the safest place in the shelter area and group the occupants there, a substantial improvement in fallout protection can usually be achieved. In shelter category "B/C", the "technical" estimate is 75 percent (ΔPF = 0.75) if all shelter occupants assume the fallout protective posture. In POPDEF, the estimate of the fraction of the shelter population actually in the protective posture, FPF, is not multiplied by the potential ΔPF to obtain a net value. Rather, the survivors in shelter are divided into two groups, one at the rated PF and one at the augmented PF. Thus, in the example shown in Table 8, 95 percent of the occupants would be assessed at a rated PF of 500 and 5 percent at a PF of 875.

The event, Medical Care, is shown at this point in the scenario because it is the third defensive action that can alter the casualty outcome without changing the location of the population. It is shown in parentheses because it has not yet been operationalized in POPDEF. Although the effect of medical care in reducing fatalities from burns and trauma has been analyzed in the past,[7,8] these analyses have not been in a form that would permit application to the fatality functions ascribed to the shelter categories developed by DCPA (Table 1). Hence, the fatality functions currently used in POPDEF and TENOS are based on minimal medical care. If new fatality functions appropriate to levels of medical care were to become available, the Medical Care function could be implemented in POPDEF in a manner analogous to the blast protective posture procedure. If all injured survivors were to receive some level of medical care, the effect would be to increase MLOP. (Medical care of non-fatal injuries would not change the number of uninjured - MCOP -- and could only contribute to one of the other measures of effectiveness discussed in Section VI, such as maximizing of the work force.) The Program Analysis Model could be expanded to produce estimates of the fraction of the population receiving medical care. The product would produce a ΔMLOP that would be additive to that produced by the blast protective posture. The effect of medical care in reducing radiation fatalities could be implemented by altering the MLDs currently used in POPDEF. Again, quantitative estimates of this effect from an authoritative source are unavailable.

The Detonation survivors shown in parentheses in Table 8 are obtained by applying the MLOP and MCOP shown in the Input column modified by ΔMLOP and ΔMCOP as previously discussed. Similar use of MTOP in the attack environment matrix defines the fraction not trapped and, by difference, the fraction of survivors trapped. MTOP is the median or 50-percent level of a

trapping function of the same form as the fatality function shown in Figure 1. It defines the fraction trapped plus killed as a function of overpressure, just as the casualty function (MCOP) defines the fraction injured and killed. In the detailed version of POPDEF, the computation program would enter such functions with the maximum overpressure incident on a particular unit area and determine the fractions killed, injured, and trapped. The proportion of the trapped who are injured would be determined by assuming that the injury rate does not differ among the trapped and the not-trapped. In the approximation version, the fact that MTOP usually lies between MCOP and MLOP creates the illusion that all of the trapped are injured; a conclusion that would not be borne out by the detailed analysis. Hence, an additional input, FTU, has been introduced in POPDEF that specifies the fraction of the trapped who are uninjured. This factor is determined by integration of the trapped-uninjured function to approximate the detailed version. FTU is not required in the detailed version. The technical basis for estimating MTOP and FTU is very limited at this time.

The Rescue activity operates on the trapped fraction. Hence, the population percentages in the Stay columns consist of those not trapped plus the survivors of those caught in the open enroute to this shelter category as discussed previously. The survivors shown in the Move column in parentheses are the fraction of the trapped who are rescued, which is determined by the input, FR, which is taken to be 75 percent in this example. This input is generated by the Program Analysis Model. The technical basis for estimates of FR is also weak. In this example, it is assumed that immediate rescue would be largely ineffective so that re-entry rescue several days after detonation would be the main rescue capability. The 25 percent not rescued are those lost in the interim, mainly because of fire. The rescued survivors are divided into those afforded remedial radiological measures (R) and those who are not (N) by FRR, which is taken to be 2 percent

in this example. POPDEF has the capability to accept differing estimates of the effectiveness of remedial movement as functions of (a) time after attack and (b) location of the survivors with respect to physical damage. Since all rescue occurs in the damaged area, only one value of FRR is necessary.

The Fire event operates on the Stay fractions shown on the Rescue line. The inputs to the calculation are FF, the fraction forced out of shelter by the fire threat, FFR, the fraction of these afforded remedial radiological measures, FFSS, the fraction of those not forced out who survive, and FFSM, the fraction who survive among those forced out. The values shown in Table 8 are based on the Program Analysis Model, which provides estimates of the effectiveness of fire protection and suppression measures. These are used in a model of fire initiation and spread that assumes that any building with a sustained fire is consumed and the occupants are forced out. Those not at fire risk remain in shelter and suffer no fire losses. Those forced out suffer fatalities according to the severity of the fire environment at the time they leave. According to the model, those forced out must leave their shelter within the first hour or so. Again, those forced out of shelter by fire originate in the damaged area; hence, FFR, the fraction afforded remedial measures is appropriate to this situation. The input, PSIF, taken to be 2 psi in Table 8, defines the overpressure level above which the fire situation exists.

The calculations for the Fire event illustrate some of the complexities incorporated into POPDEF. Consider the SI column in Table 8. The 1.93 percent of the population who are injured survivors after the Rescue event are all within the 2-psi region. Hence, the 1.72 percent remaining after the Fire event comprise 89 percent of the original 1.93 percent and the 0.21 in the MI column are the 11 percent of the injured forced out of shelter by fire (FF = 0.11). (The latter are also reduced by FFSM but the survival rate is

so high, the difference does not appear in this rounding.) However, the 0.82 percent in the MU column is only about 7 percent of the 11.53 percent uninjured in the SU column after the Rescue event. This comes about because about one-third of the uninjured survivors are in overpressure regions less than 2 psi according to the attack environment matrix underlying this example calculation. Hence, the FF of 11 percent can be assessed only on the approximately two-thirds that are in the fire area. Thus, 10.7 percent of the population remain uninjured in this shelter category and the difference, 0.83 percent, are forced out. The latter figure is then reduced by FFSM to the 0.82 percent shown. It can be seen that the computational program must account for the distribution of survivors with overpressure at each stage in the calculation in order to model survival in a reasonable way.

The Water event (lack of drinking water) applies to the SU and SI population fractions remaining in this shelter category after the Fire event. The principal inputs are FW, the fraction forced out because of lack of drinking water, and FWR, the fraction of those forced out that are afforded remedial radiological measures. Consider those "B/C" shelters that are remote from the detonation region. Lacking the provision of stored water in specially-provided containers, some fraction of these shelters will have ample supplies of drinking water in various storage tanks or may be served by a gravity-pressurized water system that would provide water even if electric power supplies were disrupted. Thus, only a portion of the sheltered population would be in "B/C" shelters where lack of drinking water could result in premature shelter-leaving. On the other hand, in the area close to detonations, storage tanks and piping would be destroyed and water mains broken. Survivors in this situation would lack drinking water.

In Table 8, FW_1 is the estimated fraction forced out because of lack of drinking water in the undamaged area. FW_2 is the fraction forced out in the

damaged region. PSIFW is the overpressure dividing these two regions. In the example calculation all survivors experiencing more than 4 psi are forced out as well as half those experiencing lower overpressures. In the calculation shown, most of the injured survivors are over the 4 psi level (MCOP = 7 psi). The exception are the injured survivors that continued on to "B/C" shelters after detonations occurred. These were in the 2-3 psi region. They comprise 1.93 - 1.85 or 0.08 percent of the population and half of them are forced out, leaving 0.04 in the SI column. The equivalent calculation for SU is explained by the fact that fully three-quarters of the 10.7 percent uninjured survivors are found at overpressures less that 4 psi when previous deductions in the scenario are taken into account.

The FWR calculation follows a similar pattern. In undamaged areas several days after attack, the effectiveness of remedial movement is seen as quite good -- $FWR_1 = 0.64$ -- whereas in damaged areas it is seen as quite poor -- $FWR_2 = 0.02$. PSIW defines the boundary of the damaged region as 2 psi in this example. Hence, all of the injured forced out, being in the damaged region, are subject to the 2-percent remedial movement. On the other hand, about 20 percent of the uninjured obtain remedial measures because many are in the undamaged region. The values of the inputs, FWR_1 and FWR_2, are generated by the Program Analysis Model, as discussed in Section IV and Appendix B.

It should be noted that at the conclusion of the Water event all survivors remaining in "B/C" shelters -- some 4.12 percent of the Risk population -- are in overpressure regions below 4 psi as the result of the estimates of FW_2 and PSIFW. These survivors are still subject to premature shelter-leaving because of an untenable heat environment in the shelter areas. This is more likely in summer months than in winter months and more likely in the South and Southwest

than in the North. As can be seen by the input values in the example in Table 8, all survivors are forced out in this event (FV = 1.0). The times at which this movement occurs as well as those for the water event are derived from the analysis of climatological and physiological variables contained in Appendix C. These times are effective times of shelter-leaving that reproduce the assessment of radiation casualties under variable leaving times in different parts of the country and at different times of the year. In particular, it is not meant that people afforded remedial movement actually leave shelters earlier than the (N) group, but merely that the effective exit time must be shorter to properly reflect the casualty ratio when remedial movement fails.

Because the Ventilation event occurs many days after the detonation, the estimate of FVR_1, which is generated by the Program Analysis Model, is substantially higher -- 82 percent effective -- than FWR_1 in undamaged areas. The effectiveness of remedial measures in damaged areas remains low during this period.

<u>The POPDEF Output</u>

The output of the POPDEF computational program summarizes the results of the calculations described above for the whole nation and for each of the three regions -- Risk, Host, and Neither. The output format and example results are given in Section V.

IV. THE PROGRAM ANALYSIS MODEL

As described in Section III, the Population Defense Model contains a number of input parameters that represent the posture of the people with respect to protection as a result of the civil defense operating capabilities built by the preparedness program. This Section describes the Program Analysis Model (PAM) which provides a means by which appropriate values for these input parameters can be estimated, given a description of a postulated civil defense preparedness program.

In essence, PAM identifies and describes relationships among elements of civil defense and defines paths through these relationships along which quantitative descriptions of elements of the preparedness program can be translated into quantitative estimates of the POPDEF input parameters. In this process, the model operates through the following steps:

1. The operating capabilities of elements of the operating system are estimated for the start of the preparedness program.

2. A preparedness program is specified by defining for each of the program elements: (a) qualitatively what is to be accomplished, (b) the amount of investment, and (c) the schedule.

3. The time of enemy attack is specified.

4. For the period between the start of the preparedness program and the attack, the effects of the preparedness program in changing the operating capabilities of the operating system are estimated and the resultant operating capabilities at the time of the attack are estimated.

5. The effects of these operating capabilities on the posture and protection of the people are estimated and, from these, estimates are made of the POPDEF input parameters.

PAM Element Structure

To provide a system element structure for PAM, the civil defense program elements were organized as shown in Table 9. These elements are explained and defined in Appendix A. This structure differs from that used in the past[1] and it can be seen to contain some elements that resemble operating system functions and others that resemble preparedness system functions. This new structure was developed in part because attempts to maintain the traditional distinction between preparedness and operating systems posed difficulties in relating preparedness activities to operating capabilities. Then, too, the program analysis technique developed for PAM usually begins with preparedness activities or calls on them at various stages of defining operating capabilities, for which a common notation was desired. This notation consists in part of the element codes shown in Table 9. This structure, then, is an outgrowth of the current developmental status of PAM. It is not necessarily exhaustive nor mutually exclusive at this point although it has gone through several revisions in its application to estimating POPDEF input parameters.

The essence of the program analysis technique and the nature of additional notation will be introduced by means of an example: the estimating of the POPDEF parameter, FPF, which is the fraction of the shelter population actually finding and occupying the shelter area giving most protection against fallout (see Table 8 and associated text). The example analysis will lay a basis for summarizing the formal technique that underlies the estimation of other POPDEF input parameters, which are provided in Appendix B.

Identification of the Elements

The first step in the PAM technique is to identify from among the elements of Table 9 those that are related to estimating FPF. One of the elements in Table 9 contributes directly to the achievement of an improved fallout posture; others support it. The first problem, then, is to identify this central element.

Table 9

SYSTEM ELEMENT STRUCTURE FOR PROGRAM ANALYSIS MODEL

Major Element	Subordinate Elements	Element Code
Shelter	Survey	SA
	Marking	SB
	Planning	-
	Community Shelter	SC
	Crisis Relocation Shelter	SD
	Shelter Production	SE
	Production	-
	Single Purpose	SF
	Slanting	SG
	Upgrading	SH
	Expedient	SI
	Ventilation	SJ
	Stocking	-
	Water	SK
	Sanitation	SL
	Food	SM
	Medical	SN
	Communications	SR
	Public (EBS)	SO
	System	SP
Crisis Relocation Planning (CRP)	Relocation Movement	XA
	Reception and Care	XB
	Revising Supply Channels	XC
	Commuting Essential Workers	XD
Warning	Increased Capability	-
	National System	AC
	Alerting	AA
	Informing	AB
	Local System	AF
	Alerting	AD
	Informing	AE
	Reduced Delay	-
	National System	AI
	Alerting	AG
	Informing	AH
	Local System	AL
	Alerting	AJ
	Informing	AK

Table 9 (Continued)

Major Element	Subordinate Elements	Element Code
Radiological Defense (RADEF)	Shelter RADEF	US
	Instruments	UA
	Monitors	UB
	Self-Help RADEF	UH
	Instruments	UC
	Monitors	UD
	Area RADEF	UW
	Instruments	UE
	Monitors	UF
	RADEF Officers	UG
Emergency Public Information (EPI)	Information Preparations	-
	Self-Help	IA
	Warning	IB
	Relocation	IC
	Shelter	ID
	Broadcast Station Protection	IE
Emergency Services		-
Fire Service	Public Preparedness	-
	Self-Help	FA
	Warning	FB
	Relocation	FC
	Shelter	FD
	Fire Prevention	-
	Self-Help	FD
	Fire Service	FF
	Fire Suppression	FG
	Rescue	FH
	Inform D&C	FI
Medical Service	Public Health	-
	Self-Help Sanitation	MA
	Medical Service Sanitation	MB
	Controlling Disease	MC
	Controlling Vectors	MD
	Medical Care	-
	Transporting	ME
	Self-Help First Aid	MF
	Service First Aid	MG
	Facility Treatment	MH
	Inform D&C	MI

Table 9 (Continued)

Major Element	Subordinate Elements	Element Code
Police Service	Public Preparedness	-
	Self-Help	LA
	Warning	LB
	Relocation	LC
	Shelter	LD
	Maintaining Order	-
	Facilities	LE
	Relocation Traffic	LF
	Movement to Shelter	LG
	Remedial Movement	LH
	Suppressing Crime	-
	Controlling Access	LI
	Controlling Criminals	LJ
	Warning	LK
	Inform D&C	LL
Warden Service	Public Preparedness	-
	Self-Help	WA
	Warning	WB
	Relocation	WC
	Shelter	WD
	Managing Movement	-
	Relocation	WE
	To Shelter	WF
	Remedial	WG
	Shelter-Based Operations	-
	Fire Fighting	WH
	Rescue	WI
	Remedial Movement	WJ
	Managing Shelters	-
	Public Information	WK
	Improve Blast Posture	WL
	Improve Fallout Posture	WM
	Operate Ventilation	WN
	Control Water Use	WO
	Shelter RADEF	WF
	Sanitation	WR
	Medical Care	WS
	Feeding	WT
	Reception and Care	WX
	Lodging	WU
	Feeding	WV
	Welfare Services	WW
	Warning	WY
	Inform D&C	WZ

Table 9 (Continued)

Major Element	Subordinate Elements	Element Code
Resource Service	Supply	-
	Revising Supply Channels	RA
	Supplying Goods	RB
	Transporting	-
	Relocation of People	RC
	Commuting Workers	RD
	Remedial Movement	RE
	Goods	RF
	Facilities	RJ
	Establishing	RG
	Operating	RH
	Maintaining & Repairing	RI
	Clearing Debris	RM
	Roads	RK
	Buildings	RL
	Decontaminating	RP
	Buildings	RN
	Terrain	RO
	Inform D&C	RR
Protect Industry	Hardening	-
	Facilities	BA
	Equipment	BB
	Inventories	BC
	Emergency Shut Down	-
	Facilities	BD
	Processes	BE
Protect Agriculture	Public Preparedness	-
	Self-Help	GA
	Shelter	GB
	Protect Livestock	-
	Protection	GC
	Feeding	GD
	Protect Crops	-
	Protect Seed Stock	GE
	Decontamination	GF
Direction and Control		
Federal D&C	Support State and Local	-
	Goods	DA
	Services	DB
	Information	DC
	Informing the Public	DD
	Warning the Public	DG
	Alerting	DE
	Informing	DF

Table 9 (Continued)

Major Element	Subordinate Elements	Element Code
State D&C	Support Local	-
	Goods	DH
	Services	DI
	Information	DJ
	Inform Federal	DK
Local D&C	Public Preparedness	-
	Self-Help	DL
	Warning	DM
	Relocation	DN
	Shelter	DO
	Warning the Public	DR
	Alerting	DP
	Informing	DQ
	Informing the Public	DS
	Informing the System	DZ
	State	DT
	Fire Service	DU
	Medical Service	DV
	Police Service	DW
	Warden Service	DX
	Resource Service	DY
Research and Development		KA
Federal Program Management	Planning	-
	Program	HA
	Operational	HB
	Procurement	-
	Facilities	HC
	Equipment	HD
	Materials	HE
	Services	HF
	Staffing	-
	Recruiting	HG
	Course Instruction	HH
	Organization Exercise	HI
	Supporting State and Local	-
	Funds	HJ
	Assistance	HK
	Information	HL
	Administration	HM

Table 9 (concluded)

Major Element	Subordinate Element	Element Code
State Program Management	Planning	-
	Program	NA
	Operational	NB
	Procurement	-
	Facilities	NC
	Equipment	ND
	Materials	NE
	Services	NF
	Staffing	-
	Recruiting	NG
	Course Instruction	NH
	Organization Exercise	NI
	Supporting Local	-
	Funds	NJ
	Assistance	NK
	Information	NL
	Inform Federal	NM
	Administration	NN
Local Program Management	Planning	-
	Program	PA
	Operational	PB
	Procurement	-
	Facilities	PC
	Equipment	PD
	Materials	PE
	Services	PF
	Staffing	-
	Recruiting	PG
	Course Instruction	PH
	Organization Exercise	PI
	Inform State	PJ
	Administration	PK

Arranging the shelter occupants in an improved fallout posture is an exercise of management of the shelter. For this, Table 9 gives: Warden Service* -- Improve Fallout Posture -- WM. This is the central countermeasure and the organizational element charged with its performance is the shelter manager.

Assuming at this point in the analysis (1) that a manager for the shelter has been recruited, trained, and assigned and (2) that he is in the shelter, the next problem is to identify which other elements of civil defense give him primary support. First, to be able to direct the people to the areas with the best protection against fallout, he needs to know where they are; i.e., in which spaces is the radiation flux the least. This information can be supplied by monitoring, from Table 9: RADEF -- Shelter RADEF -- US. And although the manager may be fully trained, he could also be very busy. Therefore, a reminder from D&C with refresher instructions would likely help him to get the people into the improved posture. For this, Table 9 gives: Shelter -- Communications -- System -- SP. Therefore, to begin with, the central countermeasure is WM and the direct supports are US and SP.

However, for any of a number of reasons, the shelter may not have a manager. But shelter RADEF may provide a monitor: RADEF -- Monitors -- UB. And current doctrine has the policemen who guide the movement to public shelter (Police Service -- Maintaining Order -- Movement to Shelter -- LG) take shelter there. Thus, the monitors and policemen can directly support the manager function as alternatives to the manager. And given shelter RADEF - US and information from D&C - SP, they could achieve an improved fallout posture although possibly not as well as the manager.

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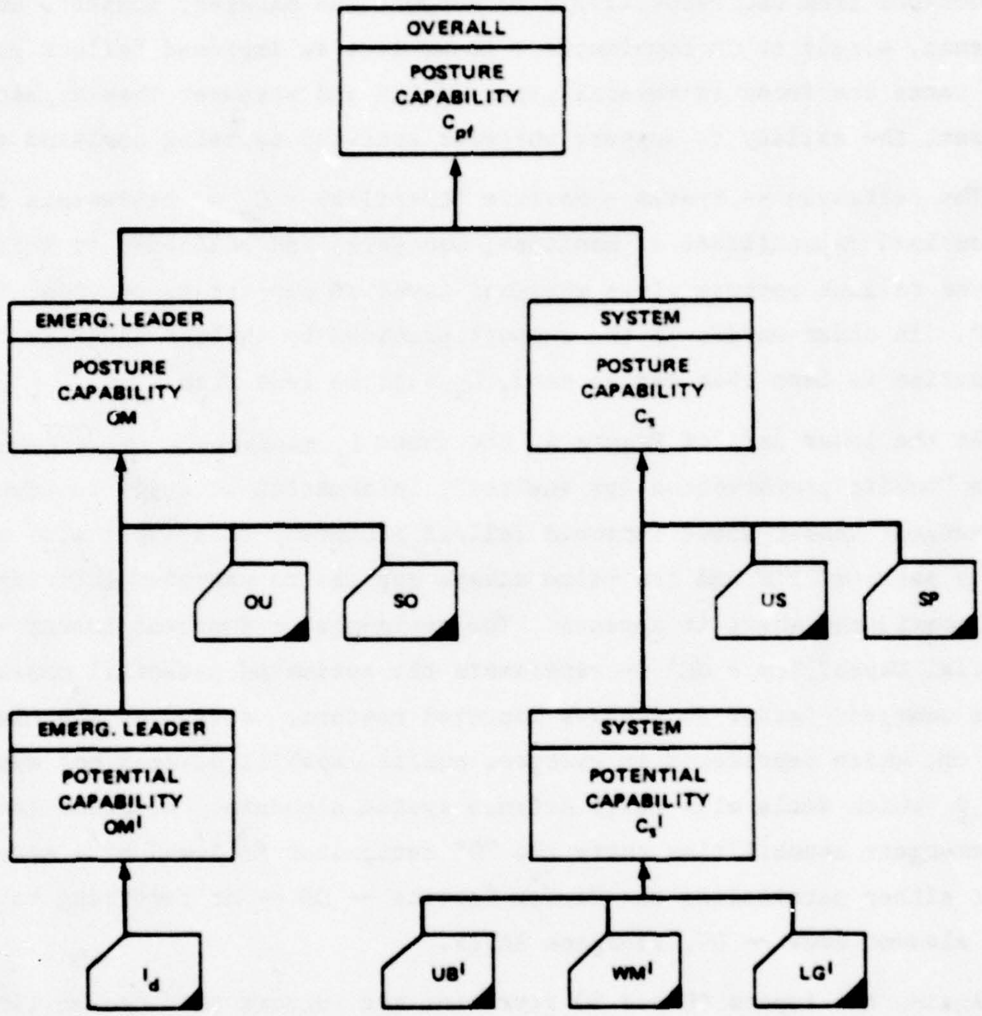
*The title "Warden Service" is used to identify an element of the civil defense organization that does not now exist but seems to be needed to perform or manage a number of the activities planned for civil defense.

Inevitably, some shelters will not have a manager, a monitor, or a policeman. Experience in shelter occupancy experiments shows that in such cases one of the occupants takes charge. This emergent leader could have some knowledge of improved fallout posture gained from civil defense information activities to prepare the public for going to shelter. If there are RADEF instruments in the shelter with instructions for their use, there can be a monitoring capability with an emergent monitor. And given support in the form of instructions from D&C (Shelter -- Communications -- Public (EBS) -- SO in Table 9) the emergent leader could also achieve an improved fallout posture although possibly not as well as those of the civil defense organization.

Figure 4 represents the capabilities discussed above. It shows the basic relationships omitting any consideration of relative capability. However, it does illustrate some of the conventions used in diagramming PAM.

Starting at the lower right, Figure 4 has three small figures of the form used to represent input cards in computer program diagrams. These -- UB', WM', and LG' -- represent capabilities of shelter monitors, shelter managers, and policemen respectively to achieve improved posture. The blackened triangle indicates that the values for these inputs come from other parts of PAM. The prime (WM') indicates that the capability is potential; i.e., it is the capability of the manager to achieve improved posture if fully supported by shelter RADEF-US and information from D&C - SP. The rectangle -- System-Potential Capability - C_s' -- represents a value calculated in this "system tree": the combined potential capabilities of monitors, managers, and policemen. The letter C is usually used in PAM to represent combined capability but, whenever it is used, its meaning is defined there.

FIGURE 4. IMPROVED FALLOUT POSTURE CAPABILITIES



The inputs US and SP represent the abilities of shelter RADEF and instructions from D&C respectively to support the manager, monitor, and policeman, singly or in combination, to achieve an improved fallout posture. These terms are found in several parts of PAM and whenever they appear, they represent the ability to support whatever activity is being analyzed there.

The rectangle -- System - Posture Capability - C_s -- represents the net combined capabilities of monitors, managers, and policemen to achieve improved fallout posture given whatever level of support is provided in US and SP. In other words, if the support provided by shelter RADEF or D&C information is less than can be used, C_s will be less than C_s'.

At the lower left of Figure 4, the input I_d represents the effectiveness of the "public preparedness for shelter", information activity in educating the emergent leader about improved fallout posture. This input also appears in many parts of PAM and its value always applies to whatever activity is being considered where it appears. The rectangle -- Emergent Leader - Potential Capability - OM' -- represents the estimated potential capability of the emergent leader to achieve improved posture. Note that the element code, OM, which represents an emergent public capability, does not appear in Table 9, which deals with civil defense system elements. As noted later, such emergent capabilities carry the "O" designator followed by a second letter either paralleling the Warden Service -- OM -- or referring to a major element code -- OU, emergent RADEF.

Again, the inputs OU and SO represent the support that can be given the emergent leader in achieving improved posture by a emergent monitor and D&C information. The rectangle -- Emergent Leader - Posture Capability - OM -- is the net capability of the emergent leader given the level of support provided by OU and SO.

Finally, at the top, C_{pf} is the combined, overall, net capability of monitors, managers, policemen, and emergent leaders to achieve an improved fallout posture.

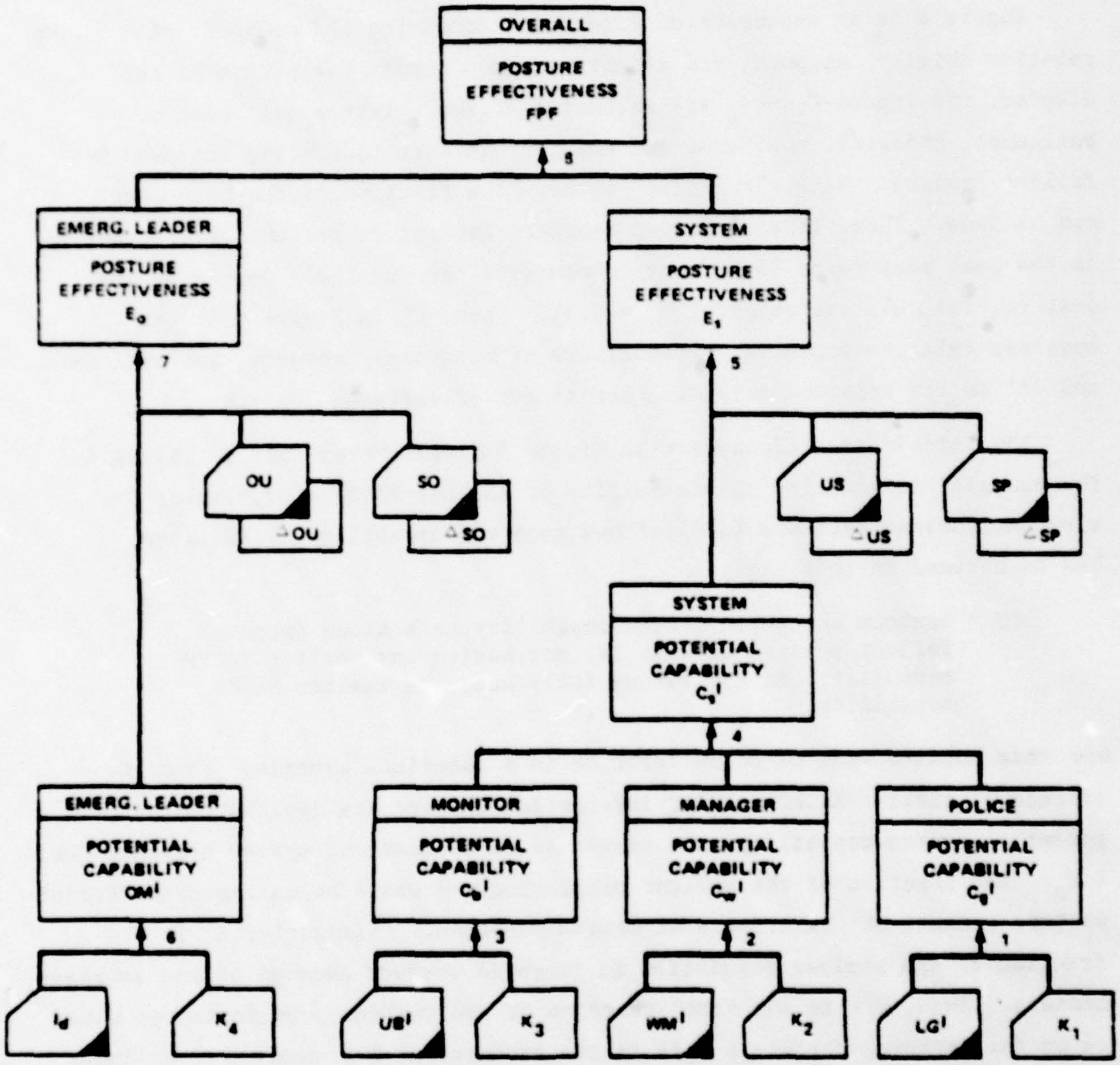
Figure 5 is an expansion of Figure 4 introducing the concepts of relative ability, support, and effectiveness. Across the bottom of the diagram, the inputs $K_1 - K_4$ are estimates of the relative abilities of policemen, managers, monitors, and emergent leaders to achieve improved fallout posture. Here, "relative" means: the fraction of the best that can be done. Then, if all shelter managers can put 85 percent of the people in the best posture or 85 percent of managers can put their people in the posture, the relative ability, $K_2 = 0.85$. Then, C_s' in Figure 5 is the combined relative potential capabilities of monitors, managers, and policemen and OM' is the relative potential capability of emergent leaders.

The introduction of support in Figure 5 differs from that in Figure 4. For example, in addition to the ability of shelter RADEF - US, Figure 5 also includes an estimate (ΔUS) of how much the capability is affected. ΔUS is defined in this case:

> ΔUS = maximum change in system capability to achieve improved fallout posture between (a) not having any shelter RADEF capability and (b) having fully adequate shelter RADEF capability.

How this applies will be shown later on in a numerical example. When the effects of shelter RADEF and D&C information support are applied to the potential system capability, the result is an estimate of system effectiveness - E_s: the fraction of the shelter population who would be in improved fallout posture because of the efforts of system personnel. Similarly, E_o is the fraction of the shelter population in improved posture because of the emergent leaders. Then, FPF is the total fraction of the shelter population who would be in the improved posture. This is the estimate of FPF desired as an input parameter for POPDEF, as described in Section III.

FIG.5 EFFECTIVENESS OF IMPROVING FALLOUT PROTECTION POSTURE – FPF



Relationships Among Elements

To demonstrate the relationships among the elements and how they are applied in PAM, the assessment of FPF described above is continued with a numerical example of the calculation of the estimate (Table 10) in a convenient form for the recording of the input values and the results of the calculations. The relationship numbers and the codes in Table 10 refer to those in Figure 5. In this example, separate estimates are made for Risk, Host, and Neither areas and for in-place and relocated mode in the Risk and Host areas; the Neither areas (NA) have only the in-place mode.

The first item, LG', is an estimate of the potential availability of policemen in public shelters to achieve an improved fallout posture if fully supported. The demonstration numbers used here represent the fraction of the population in public shelters who have in shelter with them policemen who have had some training in improving fallout posture. The second item, K_1, is an estimate of the relative ability of a policeman, given the amount of training presupposed for LG', to achieve the improved posture which was defined above to be a fraction of the best that could be done. Because the policeman is generally accepted as a member of the system organization and as having authority, K_1 is given a high value. The third item expresses the relationship (1) between K_1 and LG', their product, that yields an estimate of C'_g: the potential capability of policemen to achieve improved fallout posture if fully supported. Then, for Risk, in-place:

$$C'_g = K_1 \cdot LG' = 0.90 \times 0.20 = 0.18$$

Estimates of WM' and UB' are similarly expressed in fractions of the population in public shelters having trained managers and monitors respectively. Because of the manager's position of authority and his

Table 10

IMPROVED FALLOUT POSTURE - PUBLIC SHELTER - FPF

Relation	Item Description	Code	Area: Risk In Place	Area: Risk Reloc	Area: Host In Place	Area: Host Reloc	Area: NA
	Fract pop_1 with trained policemen in shelter	LG'	0.20	0.01	0.10	0.30	0.10
	Relative ability of police - impr fallout pos	K_1	0.90	0.90	0.90	0.90	0.90
1	$C'_g = K_1 \cdot LG'$	C'_g	0.18	0.01	0.09	0.18	0.09
	Fract pop_1 with trained manager	WM'	0.58	0.05	0.50	0.58	0.45
	Relative abil of mgr-improve fallout posture	K_2	0.90	0.90	0.90	0.90	0.90
2	$C'_w = K_2 \cdot WM'$	C'_w	0.52	0.04	0.45	0.52	0.40
	Fract pop_1 with trained monitor	UB'	0.85	0.02	0.85	0.85	0.85
	Relative abil of monitor-impr fallout post	K_3	0.75	0.75	0.75	0.75	0.75
3	$C'_b = K_3 \cdot UB'$	C'_b	0.64	0.02	0.64	0.64	0.64
4	$C'_s = C'_g + C'_w + C'_b - C'_g C_w - C'_g C'_b - \cdots$ etc.	C'_s	0.86	0.07	0.82	0.86	0.80
	Fract pop_1 with organization shelt monitoring	US	0.61	0.05	0.86	0.87	0.85
	Effect of monitoring on system capability	ΔUS	0.35	0.35	0.35	0.35	0.35
	Fract pop_1 with staff receiv D&C system info	SP	0.87	0.83	0.96	0.97	0.97
	Effect of D&C info on organization capability	ΔSP	0.40	0.40	0.40	0.40	0.40
5	$E_s = C'_s\{1 - \Delta US(1 - US)\}\{1 - \Delta SP(1 - SP)\}$	E_s	0.70	0.04	0.76	0.81	0.75
	Effect of public info in educat emerg leader	I_d	0.65	0.07	0.65	0.65	0.65
	Relative ability of emerg ldr-impr fallout pos	K_4	0.45	0.45	0.45	0.45	0.45
6	$OM' = K_4 \cdot I_d$	OM'	0.29	0.30	0.29	0.29	0.29
	Fract pop_1 with emergent monitor capability	OU	0.23	0.02	0.40	0.40	0.40
	Effect of monitoring on emerg leader capab	ΔOU	0.50	0.50	0.50	0.50	0.50
	Fract pop_1 w/emerg ldr ability receiv D&C inf	SO	0.67	0.64	0.74	0.74	0.74
	Effect of D&C info on emerg ldr capability	ΔSO	0.65	0.65	0.65	0.65	0.65
7	$E_o = OM'\{1 - \Delta OU(1 - OU)\}\{1 - \Delta SO(1 - SO)\}$	E_o	0.14	0.01	0.17	0.17	0.17
8	$FPF = E_s + E_o - E_s E_o$	FPF	0.74	0.05	0.80	0.84	0.79

training, K_2, relative ability, is also given a high value. But because the monitor would likely not be as fully trained in managing the achievement of the improved posture, his relative ability, K_3, is estimated to be somewhat less than that of policemen and managers. Calculation of C'_w in relationship 2 and C'_b in relationship 3 is the same as in relationship 1.

Because PAM is applied to the whole nation and thus to all public shelters in this case, it is equally likely that any given shelter would have a manager, a monitor, or a policeman. Thus, some shelters would have two of these; some would have all three. Therefore, to avoid double counting in calculating the combined potential capability, C'_s, PAM uses the mathematics of probability. This is appropriate because, for example, to say that WM' equals 0.58 of the population in public shelter is equivalent to saying that each individual in public shelter has a probability of 0.58 of having a trained manager in the shelter. In relationship 4, C'_s is equivalent to a contingent probability given the independent probabilities: C'_g, C'_w, and C'_b. The complete expression for relationship 4 in Table 10 is:

$$C'_s = C'_g + C'_w + C'_b - C'_gC'_w - C'_gC'_b - C'_wC'_b + C'_gC'_wC'_b$$

and for Risk, in-place:

$$C'_s = 0.18 + 0.52 + 0.64 - 0.18 \times 0.52 - 0.18 \times 0.64 - 0.52 \times 0.64$$
$$+ 0.18 \times 0.52 \times 0.64 = 0.86$$

In other words, the estimate is that 86 percent of the Risk population in public shelters would have at least one kind of CD person available who could cause them to adopt the fallout protective posture, if fully supported by RADEF and advice from D&C.

The estimated values for US in Table 10 are calculated elsewhere in PAM and, again, are expressed as fractions of the population in public shelter having a RADEF capability. The effect of monitoring on the potential

capability of organization personnel, ΔUS, is a judgement as to how much the potential capability would be reduced if there were no monitoring capability at all. In other words, the estimate of 0.35 for ΔUS means that it is estimated that the organizational personnel could not achieve the improved posture in 35 percent of the shelters if they were not supported by monitoring. In most shelters, RADEF is not essential because research and development, KA, has found which areas of these shelters and which arrangements of people result in least radiation exposure, information that could be incorporated into training and advice from D&C.

The potential capability, C'_s, would be reduced in proportion to the lack of monitoring capability: $(1 - US)$. The proportionate part of C'_s that would be lost is equal to the fraction of ΔUS measured by $(1 - US)$ or $\Delta US(1 - US)$. And the net remaining fraction of the potential capability would be what was not lost or $\{1 - \Delta US(1 - US)\}$. This remaining capability would be further reduced by the inability of organization personnel to receive guidance from D&C. Then, after allowing for the partial capabilities US and SP, the effectiveness of organization personnel (the fraction of the population in public shelters that would be in improved fallout posture because of the efforts of organization personnel) would be as shown in relationship 5:

$$E_s = C'_s\{1 - \Delta US(1 - US)\}\{1 - \Delta SP(1 - SP)\}$$

and for Risk, in-place in Table 10:

$$\begin{aligned} E_s &= 0.86\{1 - 0.35(1 - 0.61)\}\{1 - 0.40(1 - 0.87)\} \\ &= 0.70 \end{aligned}$$

The potential availability of emergent leaders to achieve improved fallout posture is I_d, which is calculated elsewhere in PAM. This item, I_d,

is an estimate of the effectiveness of public information in educating some members of the public in achieving improved fallout posture, measured in terms of the fraction of the population in public shelters who would have such a person as an emergent leader. Because of the lesser effectiveness of this method of training, the relative ability of the emergent leader was estimated to be substantially lower than that of organization personnel. Then the potential capability of emergent leaders is calculated in relationship 6 as was that of policemen in relationship 1.

The monitoring capability, OU, of emergent monitors and the ability, SO, of emergent leaders to receive instruction about fallout posture from D&C via the emergency broadcast system are calculated in other parts of PAM. The losses of potential emergent leader capability because of insufficient support -- ΔOU and ΔSO -- are treated in the same manner as ΔUS and ΔSP in relationship 5. Then, the net effectiveness of emergent leaders would be as shown in relationship 7:

$$E_o = OM'\{1 - \Delta OU(1 - OU)\}\{1 - \Delta SO(1 - SO)\}$$

and for Risk, in-place in Table 10:

$$E_o = 0.29\{1 - 0.50(1 - 0.23)\}\{1 - 0.65(1 - 0.67)\}$$
$$= 0.14$$

As before, any shelter could have system personnel or an emergent leader, or both. Then, the combined effectiveness, FPF, of system personnel and emergent leaders is found by combining their independent effectiveness probabilistically, as in relationship 4. This is shown in relationship 8:

$$FPF = E_s + E_o - E_s E_o$$

and, for Risk, in-place:

$$FPF = 0.70 + 0.14 - 0.70 \times 0.14 = 0.74$$

It will be noted in Table 10 that the estimates of FPF for the Host and NA areas are of the same order as that for the Risk, in-place area, although somewhat higher. On the other hand, FPF for Risk, relocated (0.05) is but a small fraction of the others. This may be attributed to a number of factors. In Table 10, LG', WM', and UB' are small because most organization personnel would likely have relocated. Those of the public who did not relocate evidently did not believe in relocation and would not likely concern themselves with such other civil defense matters as improved fallout posture; hence, I_d is judged quite low. In any event, it will be noted that the value used in Table 8 for the Risk area with highly effective relocation is that calculated in Table 10 for Risk, relocated.

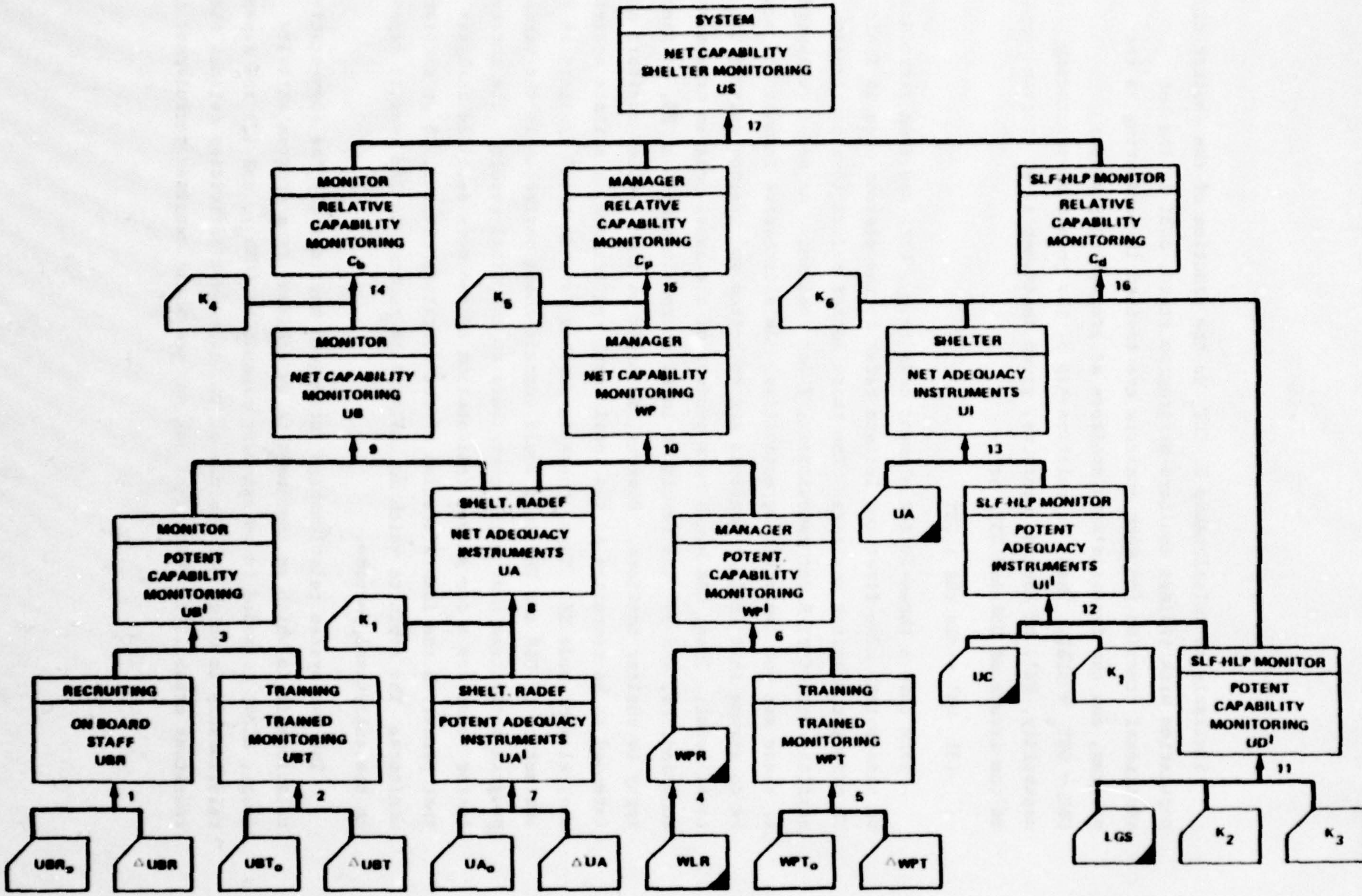
The values of FPF derived in Table 10 apply only to public shelters. But POPDEF requires an estimate of FPF for home basements in addition to that for public shelters. Home shelters would not have trained managers, monitors, or policemen. Therefore, the effectiveness of system personnel, E_s, would be zero. Only relationships 6 and 7 need be estimated for householders to obtain FPF for home basements.

The FPF system tree by itself does not include all of the system relationships used in PAM. The others are demonstrated in Figure 6. This shows the part of PAM in which estimated value for shelter monitoring, US, is calculated. This is the US that is an input in Figure 5.

Starting at relationship 1 on the lower left, UBR_o is the fraction of the population assigned to a shelter class for whom shelter monitors are on board at the start of the projected preparedness program. ΔUBR is the net additional fraction of the shelter class population for whom monitors are recruited in the preparedness program; i.e., the fraction for whom monitors are recruited less the fraction whose monitors leave the organization. Then, the fraction of the shelter class population with monitors at completion of the preparedness program is:

(1) $UBR = UBR_o + \Delta UBR$

FIGURE 6. SHELTER RADEF – ORGANIZED – US



Similarly at relationship 2, UBT_o is the fraction of the shelter class population with trained monitors at program start, ΔUBT is the net additional fraction for whom monitors are trained in monitoring in the program, and the fraction with monitors at program completion: $UBT = UBT_o + \Delta UBT$. Then, at relationship 3, the potential monitoring capability, UB', of shelter monitors, given instruments, at program completion is the lesser of UBR and UBT, or:

(3) $UB' = \text{Min } UBR : UBT$

Note that a three-letter element code (e.g., UBR) has been introduced at this point. The first two letters refer to the element code in Table 9; UB refers to shelter monitors. The third letter refers to a particular staffing activity; R for recruitment, T for training. As noted in Appendix A, these are the two staffing activities. An alternative formulation would be to assume that shelter monitors are recruited and trained only at the local level. Then, UBR would be a product of the local program management function, PG, and UBT the result of local course instruction, PH, as they apply to shelter monitors. However, it might be that shelter monitors are intended to be recruited at the local level and trained as a State activity, say, element code NK. Thus, there is another "system tree" implicit in the estimation of UBR and UBT that would connect these variables to the various program activities that might contribute to the final result. The three-letter codes are a convenient condensation of the more detailed analysis that preserves the identification of the operative element, UB or shelter monitors. The depth to which an analysis is carried in PAM usually depends on the analytical purpose.

The two system relationships introduced here are (1) the augmentative relationship in which an increment to be achieved by a program activity (e.g., ΔUBR) is added to an existing capability (UBR_o), and (2) the dependent relationship in which the minimum of two dependent activities defines the resultant capability. One might ask why one would consider recruitment and

training separately when only trained persons are of interest. One general consideration is that in many cases systems for delivery of training are well-organized and funded while recruitment is often the real limitation. Another is that persons assigned emergency responsibilities (recruited) are often not given the necessary training. A third consideration is that changes in program emphasis or advances in knowledge can invalidate prior training. For example, shelter managers now on board were not trained in adopting the fallout protective posture; hence, the retraining of these people must be assessed in estimating WM' in Table 10.

At relationship 4, the on-board strength of shelter managers need not be recalculated, because it was done in the estimating of WM', which was an input in Figure 5. However, training for monitoring (WP) differs from that for improved fallout posture (WM). Therefore, it is necessary to estimate the fraction of the shelter population for whom shelter managers are trained in monitoring, WPT at relationship 5 (augmentative), and the potential monitoring capability of managers, WP' at relationship 6 (dependent).

At relationship 7, UA_o is the fraction of the shelter population for whom shelter radiation instruments are in the shelters at program start. ΔUA is the net fraction of the shelter class population for whom instruments are procured and/or placed in the shelters in the preparedness program. Then UA' is the sum; the fraction for whom instruments are in the shelters at program completion. But monitoring instruments are not completely reliable. Therefore, at relationship 8 a reliability factor, K_1, is introduced; K_1 is defined:

> K_1 = fraction of shelter monitoring instruments that will give consistent readings when used in an actual radiation field within a shelter.

Then, the net availability of reliable monitoring instruments in the shelters is UA, the product of K_1 and UA'.

At relationship 9, the on-board strength of shelter monitors is compared to the in-shelter availability of instruments to obtain an estimate of the net monitoring capability of shelter monitors; i.e., the fraction of the shelter class population who would have monitors with instruments. Here it is logical to expect that monitors would be assigned to shelters with instruments. In this case, the two (monitors and instruments) are dependent and the net monitoring capability is the lesser:

(9) $UB = \text{Min } UB' : UA$

At relationship 10, the on-board strength of shelter managers is compared to the in-shelter availability of instruments to obtain an estimate of the net monitoring capability of managers. But here it is not logical to expect that managers would be assigned to shelters solely on the availability of instruments; many other considerations would apply. For this case, managers and instruments are independent and the net monitoring capability is the product:

(10) $WP = WP' \cdot UA$

This judgement as to dependence vs. independence is required throughout the PAM procedure. It usually requires consultation with knowledgeable persons who are familiar with how the system is intended to work.

At relationship 11, LGS is the fraction of the shelter class population for whom there are policemen controlling the movement to shelter, K_2 is the fraction of traffic policemen who are monitors, and K_3 is the ratio of traffic policemen to the number of shelters in the class*. Then, $UD' = K_2 \cdot K_3 \cdot LGS$ = potential monitoring capability of policemen in the shelter class.

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*LG' in Figure 5, is obtained from $LG' = K_3 \cdot LGS$.

At relationship 12, UC is the potential availability of police self-help monitoring instruments in the shelters if all of the instruments assigned to traffic policemen were brought to the shelters. K_1 is the reliability factor as in relationship 8. Then, assuming that all of the police monitors who have instruments bring them to the shelters, the potential availability of instruments for police monitors in the shelters would be:

(12) $UI' = \text{Min } K_1 \cdot UC' : UD'$

But some shelters would have reliable shelter monitoring instruments: UA in relationship 8. Then, there would be two potential sources of instruments for police monitors in the shelters (UA and UI') and the net availability of instruments for police monitors (to avoid double counting) would be:

(13) $UI = UA + UI' - UA \cdot UI'$

At relationships 14, 15, and 16, the factors K_4, K_5, and K_6 are the relative monitoring abilities of shelter monitors, shelter managers, and police monitors respectively. Then C_b, C_p, and C_d are the net monitoring capabilities of shelter monitors, shelter managers, and police monitors respectively. And the net, overall monitoring capability of system personnel in the shelters would be, as in relationship 4, in Figure 5.

(17) $US = C_b + C_p + C_d - C_bC_p - C_bC_d - C_pC_d + C_bC_pC_d$

The System Algebra of PAM Relationships

From the above it can be seen that there are five -- and only five -- algebraic expressions for applying system relationships in PAM. They are:

1. Augmentation: $x = a + b$. This is found wherever one quantity is increased by another without the possibility of double counting as in relationships 1, 2, 5, and 7 in Figure 6.

2. Independent: $x = a \cdot b$. This is found where one capability requires another and there is no logical basis for assuming that they will necessarily be present in the same place as in relationship 10 in Figure 6. It is

also found where a capability is modified by some characteristic that is not dependent on the capability, as in relative capabilities in Figures 5 and 6 and in instrument reliability, K_1, in relationship 8 in Figure 6.

3. Dependent: $x = \text{Min } a : b$. This is found where one capability requires another and there is a logical basis for assuming that they should be present in the same place as in relationships 9, 12, and 16 in Figure 6.

4. Redundant: $x = a + b - ab$. This is found wherever two (or more) capabilities can accomplish the same result as in relationship 4 in Figure 5 and relationships 13 and 17 in Figure 6. PAM applies nationwide and it is equally likely that at any given place capability a or capability b would apply. Some places would have both capability a and capability b. To avoid double counting, the redundant relationship uses the mathematics of probability; i.e., a and b are equivalent to the independent probabilities that capability a or capability b would occur. Then, the combined capability of a and b is the equivalent to the contingent probability of a and b: $a + b - ab$. Similar considerations apply to combinations of effectiveness and to combinations of more than two estimates of capability or effectiveness.

5. Supportive: $x = x'\{1 - \Delta a(1 - a)\}$. This occurs when an element of the system would be able to exercise all of its potential capability x' if fully supported by the capability a of another element; Δa is the difference in the capability of the supported element between having the full support of the second and not having any support by the second. This situation occurs wherever one element of the system supports another as in relationships 5 and 7 in Figure 5.

Use of Program Codes in PAM

The program elements listed in Table 9 and defined in Appendix A are large in scale; i.e., some of them include preparations for a number of related emergency operations. For example, Information Preparations - ID produces

materials for use in preparing the public for (a) making preparations for going to shelter, (b) moving to shelter, (c) improving blast and fallout postures in shelter, (d) conducting radiological monitoring in shelter, and (e) performing such shelter-based operations as fire fighting, rescue, remedial movement, and so on. To use separate codes in recording the model for each of these, one would need not only to expand ID but also to expand FD, LD, WD, and DO, the public preparedness operations, and I_d, the effectiveness of these operations, and would have caused a great proliferation in the codes.

To avoid this, we chose to use the program codes listed in Table 9 and, wherever each is used in the model, to define its meaning; i.e., to specify which thing, or capability, or effectiveness the code represented at that place in the model. This procedure, of course, established a requirement for defining the meanings of the codes throughout the development of the system trees. But it is felt that such definitions avoid ambiguity and focus attention on exactly what is being estimated at each point in the model.

Treatment of Public Participation in Civil Defense

Throughout the development of PAM it was recognized that, although a complete civil defense system in which all emergency operations everywhere are performed or managed can be a desirable objective, it may not be achievable. Therefore, at a number of places in the model, allowance is made for the public to perform some of the functions, usually with support in the form of information and guidance from D&C. In current civil defense doctrine, educating the public to perform such functions in the absence of CD organization personnel is a desirable preparedness activity.

Such public education activities have been excluded from Table 9 on the basis that emergent leaders or operators would not be specifically trained and

would not be part of the civil defense organization. In the model, public participation is signalled by codes with the major designator, "0", and generally with the subordinate designator related to the comparable code for the CD organization.

The codes used for the public in PAM are listed in Table 11.

Detailed Development of PAM

The detailed development of PAM as it now stands is shown in Appendix B. The presentation of the model is in the order of its development: starting with the POPDEF input parameter that is the PAM output and proceeding through the direct support elements and the indirect support elements. For each there is given a flow diagram (system tree) as in Figures 5 and 6. Each of these is followed by a description of the part of PAM delineated by the system tree, defining the terms and expressing the relationships in the system algebra discussed above. The order of the presentation in Appendix B is as shown in Table 12. To avoid unnecessary repetition, each part of PAM is described wherever it first appears in the analysis. When it appears later on, reference is made to where the description is to be found.

It will be noted in Table 12 that a number of the codes represent neither POPDEF input parameters nor program elements listed in Table 9 (e.g., E_o and I_d). These are intermediate estimates introduced to avoid unnecessary complexity and thus to help keep the estimating process manageable.

Table 11

PAM CODES FOR PUBLIC PARTICIPATION

OR = Fraction of public ready and willing to participate in a crisis relocation movement

OS = Fraction of public trying to inform others about crisis relocation

OW = Fraction of public trying to warn others

OL = Capability of an emergent leader to achieve improved blast posture

OM = Capability of an emergent leader to achieve improved fallout posture

SO = Capability of an emergent leader to receive and understand information from D&C

OH = Capability of an emergent leader to conduct shelter-based fire suppression

OU = Capability of an emergent monitor to perform shelter RADEF

OI = Capability of an emergent leader to conduct shelter-based rescue

OJ = Capability of an emergent leader to conduct a shelter-based remedial movement

Table 12

PROGRAM ANALYSIS MODEL

Order of Exposition in Appendix B

1. Fraction of Population Relocated in a Crisis (FCR)

Movement Effectiveness-Organizations (E_o)

Movement Effectiveness With Auto (E_f)

Movement Effectiveness-Supplied Transport (E_t)

Fraction Unable to Relocate Because of Insufficient Time (FCR_e)

Fraction of Organization Population Ready and Willing to Move (CR)

Fraction of Public Ready and Willing to Move (OR)

Supplied Transport Capability (RC)

Resource-Clear Road Debris (RK)

Police-Control Traffic (LF)

Resource-Supply Goods (RB)

D&C-System Information Capability (DZ)

D&C-Public Information Capability (DS)

Operations Plans (PB)

Police-Maintain Facility Order (LE)

Public Preparedness-Crisis Relocation (I_c)

Public Information Materials-Crisis Relocation (IC)

Organization Exercise (NI)

Organization Exercise (PI)

2. Fractions of Population at Random (FS), in Open (FE), and in Shelter (FP)

Fraction Going to Shelter (FMS)

Effectiveness of Warning Systems ($E_{s(x)}$)

Table 12 (concluded)

Warden-Movement to Shelter Capability (WF)

Public Preparedness-Warning (I_b)

Public Information Materials-Warning (IB)

Public Preparedness-Shelter (I_d)

Public Information Materials-Shelter (ID)

Movement to Shelter-Police-Control Traffic (LG)

3. Effectiveness in Improving Blast Protective Posture (ΔMLOP, ΔMCOP)

Shelter Communications (SO, SP)

4. Fractions Forced out by Fire (FF) and Surviving Fire Effects (FFS)

Fire Prevention-Occurrence of Initial Fires (a_o, b_o)

Fire Suppression Capability-Total (e_g)

Fire Suppression Capability-Organized (FG)

Public Preparedness-Self Help (I_a)

Public Information Materials-Self Help (IA)

Shelter RADEF-Organized (US)

Shelter RADEF-Emergent (OU)
Self-Help RADEF (UH)

D&C-Acquire Input Information (DZD)

5. Fraction Rescued (FR)

Rescue Capability-Organized (FH)

Rescue Capability-Shelter Manager (WI)

6. Effectiveness of Improving Fallout Protection Posture (FPF)

7. Fraction Able to Achieve Successful Remedial Movement After Leaving Shelter [F(X)R]

Effectiveness of Remedial Movement-Organized (WG)

Effectiveness of Remedial Movement-Shelter Manager (WJ)

Police-Control Remedial Movement (LH)

V. PRELIMINARY RESULTS AND ANALYSIS

The methodology reported in Sections III and IV is intended for use in the design and evaluation of civil defense programs. Given a program description sufficiently detailed to permit reasonable estimates of the many inputs to the Program Analysis Model, values of the POPDEF input parameters can be generated and calculations made of nationwide survival for one or more hypothetical nuclear attacks. The result can be compared with similar results for other programs, including a "no civil defense" case. Program costs can be introduced to allow use of a measure of effectiveness, such as cost per added survivor, as has been common practice in the past. In this application, the principal advantages of this methodology over current methods are (1) a more detailed modeling of the survival process, (2) a direct relationship between program element descriptions and system performance measures, and (3) explicit inclusion of quantitative estimates of the impact of human behavior, adverse weather, and other important constraints on survival. These characteristics suggest that survival estimates are likely to be less arbitrary and hence, more credible as predictions of performance than similar estimates made by other means.

The methodology also allows much more quantitative approaches to detailed program design. It is possible to estimate the payoff of individual program elements within the context of an overall program design; that is, to answer questions such as "How many lives do EOCs save?" This can be accomplished by parallel runs of the model in which the inputs to PAM are varied for a particular program element under consideration. The contribution of the various elements can be ranked as a basis for changes in program design to maximize predicted performance for a given program cost. Relationships among program elements can be assessed to arrive at balanced "program packages"

intended to deal with some aspect of the attack environment. Internal balances among expenditures for recruitment and training of personnel, hardware, and planning for survival operations also can be sought. These potential uses of the methodology have not yet been applied. Hence, the results presented in this section are limited to the more traditional comparison of total programs.

To aid in the analysis of results, it is useful to distinguish between "programs" and "test cases". The term, "program", will be restricted to a set of POPDEF input parameters generated by the application of PAM, which considers a specific set of program elements having a definable cost. The term, "test case", will be used whenever one or more POPDEF input parameters for a given program are adjusted arbitrarily to match those of another program in order to evaluate the change in survival due to the remaining differences between the two programs. Thus, the results for test cases are not realizable and are not to be confused with the defined programs.

Program Descriptions

Three civil defense programs will be considered. The first is the program that was recommended to the President by the Secretary of Defense in April 1978 as a result of a DoD study of civil defense options. It is presently known as Program D Prime. The key feature of the program is the development of a high-confidence crisis relocation capability that could be maintained in the evacuated mode for a month or more, if necessary. Given a crisis "surge period" of about a week, the intent is not only to relocate most residents of urbanized areas and those near key military targets but also to house and feed them and to provide fallout protection should an attack occur. These relocatees are the residents of the TR-82 risk areas. The program includes

detailed operating plans for crisis relocation and hosting, including on-site work with essential industries and organizations for employee relocation, commuting of work shifts, and on-shift protective measures. Simulation exercises are included to train the essential forces and to improve the effectiveness of the plans. In-place shelter protection planning is also included since a decision to relocate the risk population is not a certainty.

Shelter protection in risk areas is based on best use of shelter in existing facilities. An all-effects survey is programmed to provide the basis for in-place planning. In addition, the program calls for 9 million high-performance shelter spaces for key workers after crisis relocation. A host-area survey effort is included to identify suitable facilities for housing and feeding relocated persons, identify all facilities offering fallout protection, and identify other facilities that could be upgraded in a crisis to provide fallout protection. Detailed plans for shelter upgrading are included. Water containers, sanitation kits and ventilation devices are procured for host-area shelters and key-worker shelters in risk areas.

Program D Prime includes a Federally funded backbone system of EOCs and protected broadcast stations, improved warning and communications, radiological instrument procurement, and extensive training of shelter managers and radiological defense personnel. This program is estimated to cost $1.89 billion over a 7-year deployment period, based on 1978 dollars.

The second program that will be considered is one that maintains the current capability for protection of the population. This capability provides in-place protection only, based on the National Shelter Survey inventory. To maintain the current capability in the face of population growth and other changes and degradations is estimated to cost $640 million over a period of 7 years in 1978 dollars.

The third program provides, in addition to maintaining the current in-place capability, the development of austere plans for relocating the TR-82 risk-area residents in a crisis period. These paper plans would not include detailed operational plans nor the exercising of such plans and are estimated to cost about one-half of the planning effort entailed in Program D Prime. The overall cost of this program is estimated to be $790 million over a 7-year period in 1978 dollars.

Evaluation Scenario

The three programs described above are evaluated on the basis that a crisis occurs seven years hence; that is, at the completion of Program D Prime. In all cases, the crisis escalates to a confrontation between the superpowers, at which time a "surge period" of preparedness activity occurs. After a week of surge activity, a nuclear exchange occurs. The amount of relocation of risk-area residents during the crisis and surge period is evaluated alternatively under the assumption that no Presidential order to relocate occurs (spontaneous evacuation only) and under the assumption that a timely Presidential declaration precipitates implementation of crisis relocation plans. Thus, four defensive postures are analyzed. Program D Prime is evaluated under the assumptions that no Presidential order occurs (DIP) and that a full relocation occurs (DRE). The second program, current capability maintained (CCM), does not have a relocation option and hence a Presidential order is immaterial. The paper-plans-only program (PPO) assumes a Presidential declaration to implement the plans, since with no such order, the posture is essentially the same as CCM.

Assumed Attacks

The performances of the three programs under the conditions described above are assessed for three hypothetical attacks. All three attacks employ surface

detonations and average October winds for determination of fallout levels in the TENOS model. Two of the attacks (A and B) are large-scale attacks aimed at military and urban-industrial targets in the continental U.S., after varied assumptions as to allocation of a SALT-limited Soviet capability to this target system, to other worldwide targets, and to a strategic reserve. Attack A is an attack based on a largely unMIRVed Soviet threat that was used to generate the risk areas of TR-82.[6] It places about 55 percent of the resident population in the direct-effects region of detonations. Attack B is an attack that is substantially larger than Attack A and based on a highly MIRVed Soviet threat. It places about 65 percent of the resident population in the direct-effects region of detonations.

Both Attack A and Attack B are regarded as "design case" attacks; that is, they represent large-scale attacks against likely counterforce and countervalue target systems that could occur in the mid- to late-1980s. The crisis relocation option of Program D Prime and its "paper-plans-only" relative are designed against attacks of this nature. Attack C, on the other hand, is an "off-design case". It expands the dimensions of Attack B by decreasing the allocation of weapons to worldwide target systems and to strategic reserve and directs the additional weapons to cities in the host areas outside the urbanized areas. The population of these smaller cities (10,000 to 50,000 population) temporarily could become several times larger after a crisis relocation unless measures were taken to avoid such growth. It is assumed that such measures are not included in Program D Prime and hence, Attack C is a "people-hunting" attack expressly aimed at population targets created by crisis relocation. Attack C is considered an "off-design" attack because it is counter to Soviet declarative policy, borrows weapons from more important target systems, and has not been considered likely in the design of Program D Prime. As the largest of the three attacks, it places about 75 percent of the resident population in the direct-effects region of detonations.

POPDEF Inputs

To perform the casualty assessment using POPDEF, it is necessary to estimate the POPDEF input parameters shown in Table 8. Some of these inputs are "technical" estimates and some are estimated by the use of the Program Analysis Model of Appendix B. In either case, the estimates are subject to uncertainties. To account for these uncertainties, the POPDEF model has been linked to a Monte Carlo computational routine, as reported in the companion report.[2] In that effort, detailed estimates of the range of uncertainty in POPDEF and PAM input parameters have been made by the professional staff of DCPA. For this report, the "best" or "most likely" estimates from the companion report have been adopted. Reference 2 should be consulted for the justification of these estimates. The POPDEF input estimates used in this report are summarized below.

The estimates of FCR, the fraction of the risk population relocated in the host areas at the time of attack are: 0.77 for Program D Prime relocated (DRE), 0.27 for Program D Prime with spontaneous evacuation only (DIP), 0.39 for PPO, and 0.16 for the current capability maintained (CCM). For Program D Prime, the shelter categories discussed in Section II are used with the addition of two crisis-produced categories: Category Y for key-worker shelter and Category XU for upgraded fallout shelter. The POPDEF input estimates associated with shelter classes are shown in Table 13 for Program D Prime relocated (DRE). Corresponding estimates for DIP are given in Table 14.

The shelter categories for CCM and PPO reflect the lack of all-effects survey data and community shelter planning in these programs. Four categories are specified in addition to the "random" category. They are home basements (Category D), belowground NSS spaces (a combination of Categories A, B, C,

Table 13

POPDEF INPUT PARAMETERS FOR SHELTER CATEGORIES

PROGRAM DRE

Input Parameter		Random	A	B/C	D	E/F	G/H/I	Y	XU
FA	Risk Areas	0.204	0.054	0.293	0.256	0.043	0.02	0.13	-
	Host Areas	-	0.034	0.155	0.135	0.03	0.101	-	0.545
	Neither Areas	-	0.01	0.267	0.499	0.028	0.071	-	0.125
FS	Risk Areas	-	0.12	0.12	0.11	0.12	0.12	-	0.12
	Host Areas	-	0.05	0.05	0.05	0.05	0.05	-	0.05
	Neither Areas	-	0.05	0.05	0.05	0.05	0.05	-	0.05
FE		-	0.03	0.03	-	0.03	0.03	-	0.03
MLOP(psi)		5	50	10	10	8	5	55	5
ΔMLOP	Risk Areas	-	0.01	0.03	0.01	0.01	0.04	-	0.01
	Host Areas	-	0.07	0.23	0.05	0.07	0.40	-	0.07
	Neither Areas	-	0.06	0.20	0.05	0.06	0.34	-	0.06
MCOP(psi)		2	35	7	4	2	2	45	2
ΔMCOP	Risk Areas	-	0.01	0.03	0.04	0.08	0.04	-	0.01
	Host Areas	-	0.07	0.23	0.27	0.66	0.33	-	0.07
	Neither Areas	-	0.06	0.20	0.27	0.56	0.28	-	0.06
PF		10	5000	500	25	55	70	200	40
ΔPF		-	-	0.75	1.0	1.0	1.0	-	0.75
FTU		0.06	0.12	0.20	0.02	0.01	0.02	0.11	0.02
FR		0.97	1.0	0.75	0.74	0.81	0.97	1.0	0.97
FF		0.03	-	0.11	0.13	0.10	0.03	-	0.03
FFSM		1.0	1.0	0.99	0.98	0.99	1.0	1.0	1.0
FPF	Risk Areas	-	-	0.05	0.02	0.05	0.05	-	0.05
	Host Areas	-	-	0.84	0.23	0.84	0.84	-	0.84
	Neither Areas	-	-	0.79	0.23	0.79	0.79	-	0.79
FRR		0.02	0.02	0.02	0.01	0.02	0.02	0.02	0.02
FFR		-	-	-	-	-	-	-	-
FWR(over 2psi)		0.02	0.02	0.02	0.01	0.02	0.02	0.02	0.02
(under 2 psi)		0.64	0.64	0.64	0.22	0.64	0.64	0.64	0.64
FVR(over 2 psi)		0.02	0.02	0.02	0.01	0.02	0.02	0.02	0.02
(under 2 psi)		0.82	0.82	0.82	0.50	0.82	0.82	0.82	0.82
FER(over 2 psi)		0.02	0.02	0.02	0.01	0.02	0.02	0.02	0.02
(under 2 psi)		0.82	0.82	0.82	0.50	0.82	0.82	0.82	0.82

Table 14

POPDEF INPUT PARAMETERS FOR SHELTER CATEGORIES

PROGRAM DIP

Input Parameter		Random	A	B/C	D	E/F	G/H/I	Y	XU
FA	Risk Areas	0.213	0.062	0.337	0.295	0.049	0.023	0.021	
	Host Areas	-	0.046	0.233	0.220	0.02	0.144	-	0.337
	Neither Areas	-	0.01	0.267	0.499	0.028	0.071	-	0.125
FS	Risk Areas	-	0.12	0.12	0.11	0.12	0.12	-	0.12
	Host Areas	-	0.05	0.05	0.05	0.05	0.05	-	0.05
	Neither Areas	-	0.05	0.05	0.05	0.05	0.05	-	0.05
FE		-	0.03	0.03	-	0.03	0.03	-	0.03
MLOP (psi)		5	50	10	10	8	5	55	5
ΔMLOP	Risk Areas	-	0.07	0.24	0.05	0.07	0.41	-	0.07
	Host Areas	-	0.06	0.21	0.05	0.06	0.37	-	0.06
	Neither Areas	-	0.06	0.20	0.05	0.06	0.34	-	0.06
MCOP (psi)		2	35	7	4	2	2	45	2
ΔMCOP	Risk Areas	-	0.07	0.24	0.32	0.68	0.34	-	0.07
	Host Areas	-	0.06	0.21	0.27	0.61	0.30	-	0.06
	Neither Areas	-	0.06	0.20	0.27	0.56	0.28	-	0.06
PF		10	5000	500	25	55	70	200	40
ΔPF		-	-	0.75	1.0	1.0	1.0	-	0.75
FTU		0.06	0.12	0.20	0.02	0.01	0.02	0.11	0.02
FR		0.97	1.0	0.79	0.76	0.83	0.99	1.0	0.99
FF		0.03	-	0.08	0.12	0.09	0.01	-	0.01
FFSM		1.0	1.0	0.99	0.98	0.99	1.0	1.0	1.0
FPF	Risk Areas	-	-	0.75	0.23	0.75	0.75	-	0.75
	Host Areas	-	-	0.80	0.23	0.80	0.80	-	0.80
	Neither Areas	-	-	0.79	0.23	0.79	0.79	-	0.79
FRR		0.21	0.21	0.21	0.11	0.21	0.21	0.21	0.21
FFR		0.13	0.13	0.13	0.05	0.13	0.13	0.13	0.13
FWR	(over 2 psi)	0.21	0.21	0.21	0.11	0.21	0.21	0.21	0.21
	(under 2 psi)	0.65	0.65	0.65	0.22	0.65	0.65	0.65	0.65
FVR	(over 2 psi)	0.22	0.22	0.22	0.13	0.22	0.22	0.22	0.22
	(under 2 psi)	0.78	0.78	0.78	0.37	0.78	0.78	0.78	0.78
FER	(over 2 psi)	0.22	0.22	0.22	0.13	0.22	0.22	0.22	0.22
	(under 2 psi)	0.78	0.78	0.78	0.37	0.78	0.78	0.78	0.78

and G in Table 1), aboveground NSS (Categories E, F, H, and I), and a special category that represents the efforts of a portion of the basementless public to follow instructions on how to upgrade fallout protection in residences. The POPDEF input estimates associated with these shelter classes for the current capability maintained (CCM) are given in Table 15. These inputs also apply to PPO (paper plans only) except that a revised shelter assignment (FA) is used to account for the additional relocation to the host areas.

Input parameters common to all postures are: MTOP is taken to be 0.88 times the MLOP for all shelter classes; those caught in the open are assessed at an MLOP of 3 psi and an MCOP of 2 psi, with the survivors considered to proceed to their assigned shelter; FFSS is taken to be unity for all shelter classes; fire effects are limited to the region experiencing a blast overpressure greater than 2 psi (PSIF = 2 psi); and the blast overpressure that destroys water supplies is 4 psi (PSIFW = 4 psi). Below this level, water is assumed to be available in tanks in all residences and in half the public shelters. An exception is in the host areas for Program D Prime where all public shelters have stocked water. Ventilation is considered adequate (FV = 0) for all shelter classes except NSS basements and upgraded fallout shelter where FV equals 1.0 except in the host areas for Program D Prime where ventilation kits are provided. The event times used are those shown in Table 8.

The POPDEF Output

The results of the POPDEF casualty computations can be printed out in varying amounts of detail as needed for purposes of analysis. The highest level of aggregation is the national summary, an example of which is shown

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EFFECTIVENESS OF CIVIL DEFENSE SYSTEMS.(U)

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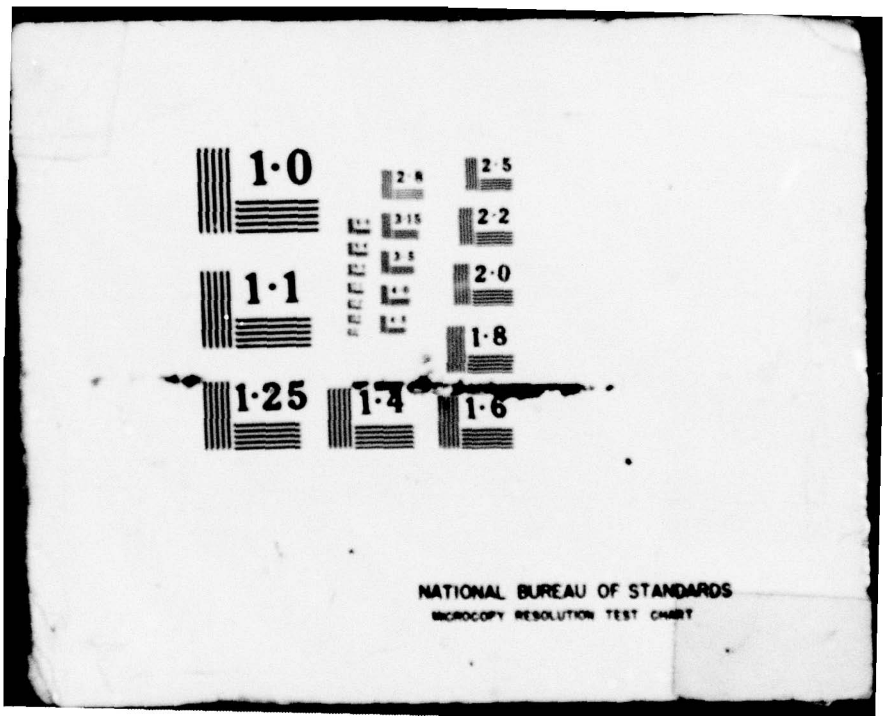
1·0
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NATIONAL BUREAU OF STANDARDS
MICROCOPY RESOLUTION TEST CHART

Table 15

POPDEF INPUT PARAMETERS FOR SHELTER CATEGORIES

PROGRAM CCM

Input Parameter		Random	Home Basements	Belowground NSS	Aboveground NSS	Upgraded Residences
FA	Risk Areas	0.234	0.549	0.146	0.015	0.056
	Host Areas	0.471	0.356	0.077	0.008	0.088
	Neither Areas	0.122	0.748	0.042	0.010	0.078
FS	Risk Areas	-	0.42	0.47	0.47	0.47
	Host Areas	-	0.05	0.05	0.05	0.05
	Neither Areas	-	0.05	0.05	0.05	0.05
FE		-	-	0.12	0.12	-
MLOP (psi)		5	10	7	5	5
ΔMLOP	Risk Areas	-	0.01	0.05	0.01	-
	Host Areas	-	-	0.04	0.01	-
	Neither Areas	-	-	0.04	0.01	-
MCOP (psi)		2	4	4	2	2
ΔMCOP	Risk Areas	-	0.04	0.05	0.13	-
	Host Areas	-	0.03	0.04	0.10	-
	Neither Areas	-	0.03	0.04	0.10	-
PF		10	25	100	70	50
ΔPF		-	1.0	0.75	1.0	-
FTU		0.06	0.02	0.20	0.02	0.06
FR		0.81	0.63	0.66	0.69	0.83
FF		0.04	0.16	0.13	0.12	0.04
FFSM		1.0	0.98	0.99	0.99	1.0
FPF	Risk Areas	-	0.02	0.21	0.21	-
	Host Areas	-	0.02	0.19	0.19	-
	Neither Areas	-	0.02	0.19	0.19	-
FRR		0.02	0.02	0.04	0.04	0.02
FFR		0.02	0.02	0.02	0.02	0.02
FWR	(over 2 psi)	0.02	0.02	0.04	0.04	0.02
	(under 2 psi)	0.03	0.03	0.08	0.08	0.03
FVR	(over 2 psi)	-	-	0.05	-	-
	(under 2 psi)	-	-	0.10	-	-
FER	(over 2 psi)	0.02	0.02	0.05	0.05	0.02
	(under 2 psi)	0.03	0.03	0.10	0.10	0.03

in Table 16. Similar summaries can be requested for the three regions: Risk, Host, and Neither. Within each region, detailed printouts can be obtained for each shelter class. The latter are in the format of Table 8 except for omission of the listing of input parameter values. Each shelter class event tableau is followed by a casualty summary like that in Table 16.

The casualty summary consists of three tables in sequence. The uppermost table records total survivors (in millions) by event, as assessed from the "Move" columns of the event tableau. Those afforded remedial radiological measures are shown separately from those who are not. Within these categories, those uninjured (MU) and injured (MI) by direct effects are shown.

Next in Table 16 is the record of the subset of survivors who are uninjured from fallout radiation; that is, those whose ERD is less than 200 Roentgens if blast injured or less than 250 R if not injured. The differences between these entries and the corresponding entries in the upper table are those survivors suffering radiation injury.

At the bottom of Table 16 are the summaries of survivors and fatalities by cause. The "Not Injured" is the sum of the MU columns in the "Radiation Uninjured" table. The blast injured value is the sum of the MI columns in the same table. The radiation injured are obtained from the differences between the MU columns in the two upper tables and those injured by both blast and radiation are obtained in a similar fashion from the MI columns. By dividing any entry by the population base shown at the top of the table, the results can be expressed in terms of fractional survival. In Table 16, which is for Program DRE under Attack A, the overall survival rate is about 87 percent. About 80 percent of the population are uninjured survivors. The fatalities are about equally due to blast and radiation, with a small "other" contribution from fire and lack of rescue.

Table 16

EXAMPLE POPDEF OUTPUT
(Program DRE -- Attack A)

Population = 211.774

TOTAL SURVIVORS

	REMEDIAL		NON-REMEDIAL	
	MU	MI	MU	MI
Rescue	.013	.128	.064	.564
Fire	.000	.000	.326	.095
Water	1.867	.188	4.682	1.487
Vent	.474	.012	.600	.059
Emergence	131.559	.334	40.360	.662
Subtotal	133.913	.662	46.032	2.867

RADIATION UNINJURED

	REMEDIAL		NON-REMEDIAL	
	MU	MI	MU	MI
Rescue	.012	.115	.053	.430
Fire	.000	.000	.225	.063
Water	1.712	.154	3.744	1.072
Vent	420	.011	.516	.051
Emergence	127.193	.301	35.693	.503
Subtotal	129.337	.581	40.232	2.119

ULTIMATE SURVIVORS		FATALITIES	
Not Injured	169.569	Blast	15.290
Blast Injured	2.700	Radiation	12.786
Radiation Injured	10.376	Other	.224
Blast Radiation Injured	.829		
TOTAL	183.474	TOTAL	28.300

Presentation of Results

The essential results of the assessment of the four programs under the three hypothetical attacks are displayed in Figure 7. Program D Prime relocated (DRE) and the paper-plans-only program (PPO) are grouped together, since both assume a Presidential order to implement crisis relocation. Program D Prime in-place (DIP) is compared with the Current Capability Maintained (CCM), since only spontaneous evacuation is assumed in these programs. Some general observations can be made from these results. As one might expect, the performance of all programs decreases as the attack weight increases but the low-cost programs are degraded more severely. Under the "people-hunting" Attack C, both Program D Prime postures (DRE and DIP) maintain about two-thirds of their performance under Attack A whereas PPO and CCM fall to about half their performance under Attack A.

Comparing the two crisis relocation programs, DRE adds about 27% of the population as survivors over PPO, almost independent of attack weight. In terms of uninjured survivors, DRE adds about one-third of the population relative to PPO for Attacks A and B, the "design" attacks, falling to one-quarter of the population for the "off-design" attack. In absolute terms, DRE provides high survivorship under the design attacks (74 to 87 percent) as compared with the 46 to 60 percent survivors for PPO. Indeed, DRE performs as well under the "people-hunting" attack as does PPO under the less severe design attacks.

Comparing the spontaneous evacuation cases, DIP adds about 17 percent of the population as survivors over CCM, again independent of attack weight, and 20% of the population are added uninjured survivors for the design attacks. In absolute terms, DIP performance is 78 percent of DRE for Attack A, falling slightly with increasing attack weight to 74 percent for Attack C. The current capability, CCM, on the other hand, provides 60 percent of the DRE

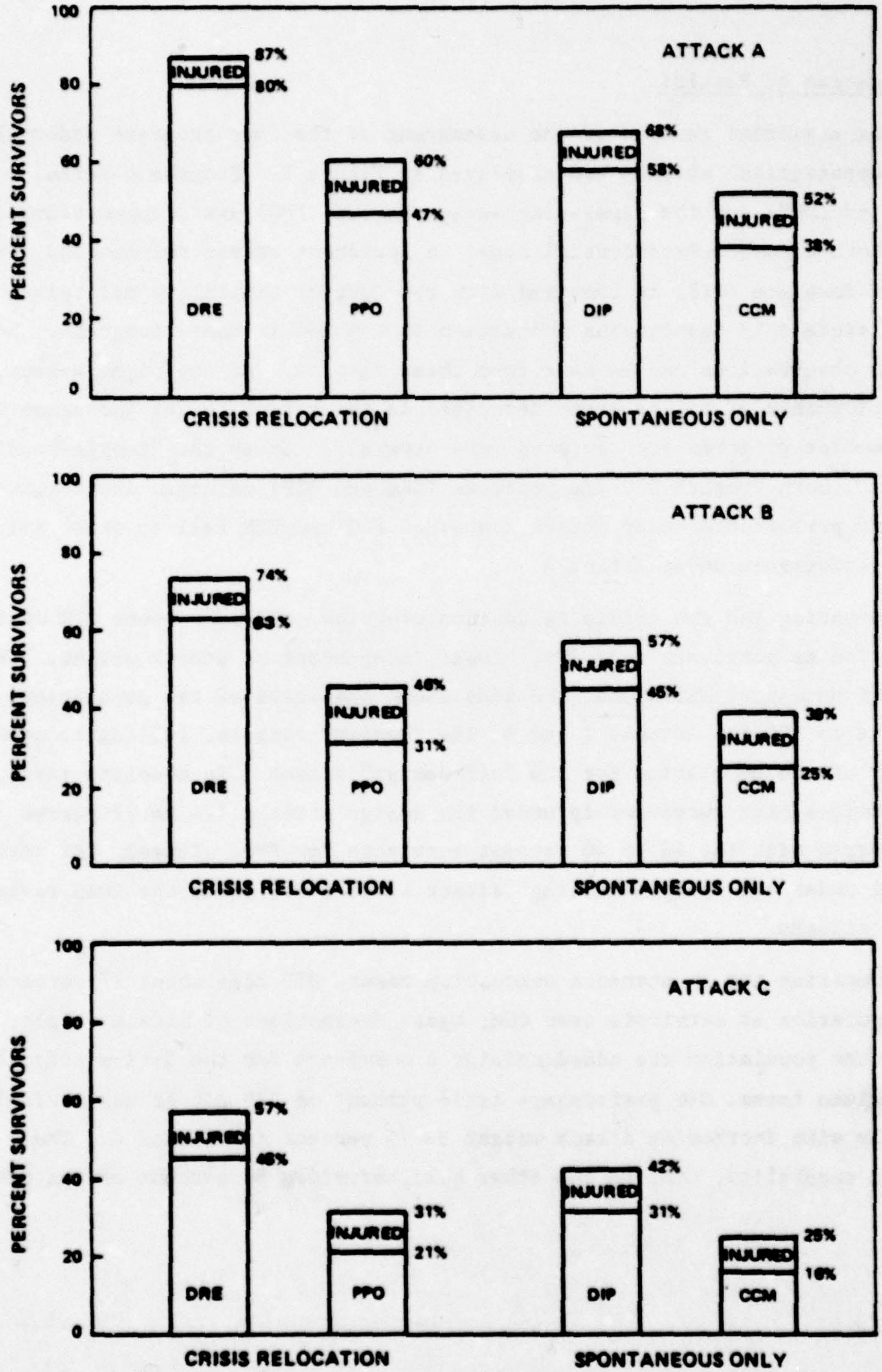

FIGURE 7. COMPUTATIONAL RESULTS

survivorship under Attack A and degrades to less than half for Attack C. It should also be noted that Program D Prime without a Presidential relocation order (DIP) out-performs the paper-plans-only program (PPO) for all attacks, even though its additional investment in crisis relocation capability is largely unused. This finding suggests that the characteristics of Program D Prime other than those concerned with relocation have a strong bearing on its lifesaving performance.

Test Case Comparisons

To explore the relative contribution of major program elements, one can construct appropriate test cases that arbitrarily fix the values of one of the POPDEF input parameters for comparison purposes. Such a comparison is shown in Figure 8, in which the effectiveness of crisis relocation after a Presidential order is removed from consideration. For this purpose, we introduce Test Case 1, which has all of the performance characteristics of PPO except that the fraction of the risk population relocated to the host areas (FCR) is inflated to match that estimated for Program D Prime. As noted before, this test case is not a deployable program. To match the estimated FCR for Program D Prime, one would need to add to PPO all of the Program D Prime program elements that contribute to FCR in the PAM procedures of Appendix B. But these additions also would affect other POPDEF input parameters not considered in the test case. In Test Case 1, FCR is set arbitrarily at 0.77, a revised shelter assignment is introduced to account for the additional relocation of people to the host area using the CCM shelter classes, and the attack environment matrices also are adjusted to account for the relocation. Otherwise, all of the CCM input parameters pertain.

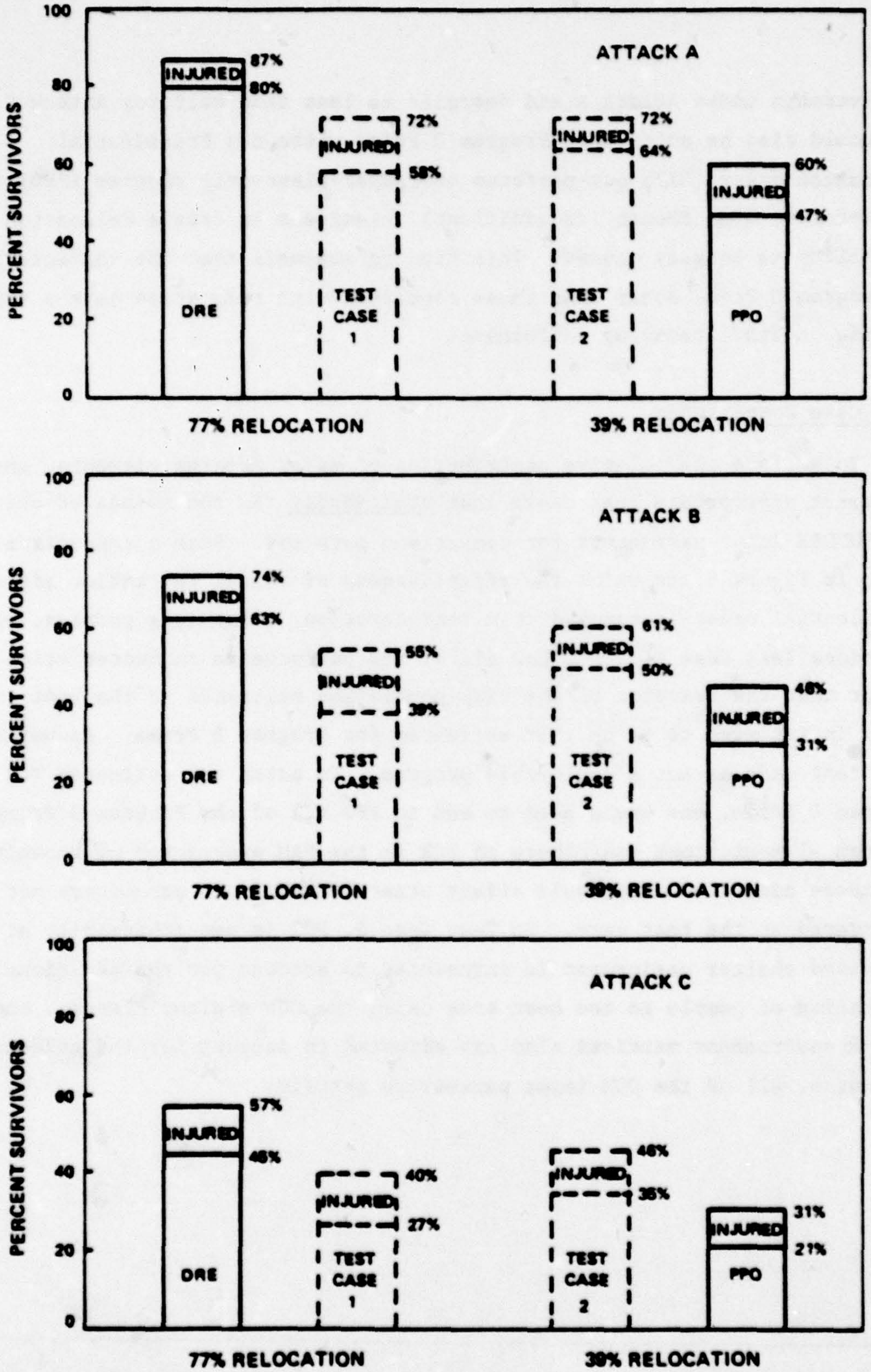

FIGURE 8. COMPARISON AT SAME FCR

Similarly, we can introduce Test Case 2, in which the FCR of Program D Prime is arbitrarily constrained to match that estimated for PPO. Thus, in effect, those elements of Program D Prime other than crisis relocation are compared with those of PPO at two levels of relocation, 77 percent and 39 percent. At the high relocation level, Program D Prime adds 15 to 19 percent of the population as survivors over Test Case 1 over the range of attacks. At the lower relocation level, the constrained Program D Prime (Test Case 2) provides 12 to 15 percent of the population as added survivors over PPO. This somewhat lower differential performance indicates that the additional elements in Program D Prime -- shelter survey and planning, shelter stocks in host areas, better radiological instruments and training, more survivable D&C, and the like -- are most effective in the host areas and hence, at high levels of crisis relocation. Similar conclusions can be reached with respect to uninjured survivors.

In Attack A, Program D Prime (DRE) increases the survivors by 27 percent of the total population over PPO (87 percent less 60 percent). The 12 to 15 percent added by the test case comparison is about half the total (44 to 56 percent), indicating that the non-relocation elements of Program D Prime contribute about equally with the improved relocation elements. This finding is confirmed by the observation that the two test cases yield the same total survivors. In Attack B, the heavier design attack, the 15 to 19 percent differential established by the test cases represents about 60 percent (54 to 68 percent) of the survivors added by DRE over PPO. In other words, the non-relocation elements of Program D Prime contribute more to survivorship than do the relocation elements. This finding is confirmed by the observation that, for the heavier Attack B, Program D Prime constrained to the lower relocation effectiveness (Test Case 2) saves more lives than the paper-plans-only program inflated to the higher relocation effectiveness (Test Case 1). Again, similar conclusions can be drawn for Attack C, the off-design attack.

The foregoing is an example of how test cases can be used to provide insight into the relative contribution of program elements. Other test cases can be constructed to allow analysis of pertinent program elements or program packages. For example, one could arbitrarily inflate PPO by providing the same sheltering capability (FA) as in Program D Prime, or one could constrain Program D Prime to the shelter potential of PPO and CCM. Thus, the shelter survey, shelter development, and shelter use planning elements of Program D Prime could be balanced off to permit evaluation of the remaining program differences.

Effectiveness Relative to Cost

A cost-effectiveness ratio, such as dollars invested per uninjured survivor or program dollars per survivor added relative to some base case, is often used in program design and evaluation. Such measures or figures of merit, although useful, are subject to a number of limitations. One difficulty is that in population defense as in most other endeavors the cost-effectiveness ratio grows as effectiveness increases. That is, very modest investments in program funds can yield substantial additional survivors compared to a baseline of poor preparedness. On the other hand, saving nearly everyone will be found to be very costly, if feasible at all. In general, the cost per survivor will increase as more and more survivors are striven for in program design. Hence, high-performance programs not only cost more than low-performance programs but also usually have a higher cost-effectiveness ratio. For this reason, it is preferable to hold one of the factors constant in program design; that is, to seek the least-cost program for a given effectiveness or the most effective program for a given cost. In practice, it may not be possible to do this and the comparison of major program options of the kind discussed here is a case in point. When evaluating programs or program elements of widely varying performance and cost, it is necessary to consider cost-effectiveness ratios in light of relative effectiveness as well.

Another hazard of applying cost-effectiveness measures to program analysis is that such measures are usually sensitive to off-design assumptions, such as the nature of the attack or gross changes in the evaluation scenario. Attack C is one example. The effectiveness of all programs is least for this attack and the cost per survivor highest. Yet, it is possible to improve the performance of all programs against this attack at little additional cost by redefining the Risk, Host, and Neither areas to avoid hosting in outlying cities over some population size. Similarly, the introduction of a pure counterforce attack into the analysis would have the effect of increasing the survivors for all programs and increasing their cost per added survivor, since much of the designed capability would not be used. The comparison of crisis reloca-programs with programs designed for a short-warning contingency offers similar problems.

With these caveats, some considerations of costs and effectiveness are shown in Figure 9.* In the upper chart, the performance of CCM, PPO, and DRE are plotted against their 7-year program costs. (The choice of a suitable time horizon for program costing is another analytical problem.) The performances under each of the three attacks, A, B, and C, have been connected by curves for illustrative purposes. In some analyses, such as that in Reference 5, such curves are avoided, although the eye tends to introduce them. The reason is that there is no assurance that a deployable program costing, say, 1.2 billion dollars would have the performances implied by the curves. On the other hand, if the given programs have merit, the trend curve might be useful in judging the merit of some other relocation-oriented program with performances substantially above or below the trend curves. The curves are introduced to illustrate the trend only, which is that performance in terms of percent survivors increases with increasing program investment and that the cost per added survivor also increases, as indicated by the decreasing slope of the curves. Only the crisis relocation options are presented, with CCM regarded as a baseline in which a Presidential relocation order is more or less immaterial. DIP is not included. If it were, it would show the same

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*Figure 9 is based on costs described on page 77 and performance shown in Figure 7.

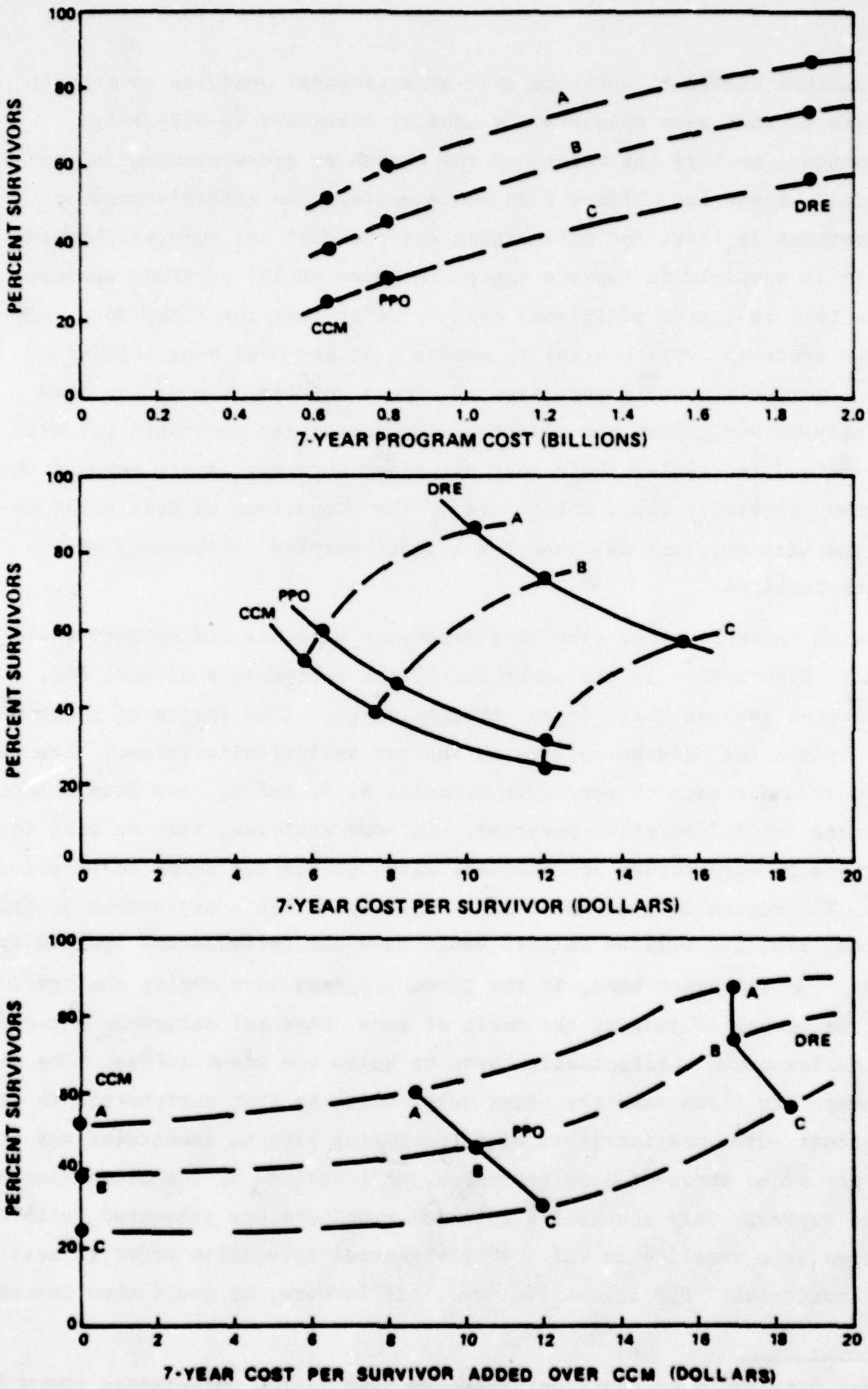

FIGURE 9. COMPARISONS OF COST AND EFFECTIVENESS

cost as DRE but lower survival levels. It appropriately could be compared, along with CCM, with other in-place program options not specified here.

In the middle chart, the information in the upper chart is repeated with the abscissa changed from 7-year program cost to 7-year cost per survivor. Specifically, the percent survivors provided by each program for a given attack is reconverted to millions of survivors, as shown in the POPDEF output tables, and divided into the program cost to yield cost per survivor in dollars. These costs range from a low of about \$6 to a high of about \$16. Two kinds of trend lines are shown. The solid curves trace the decreasing performance and increasing cost per survivor for each program as the attack weight increases from Attack A to Attack C. The dashed curves trace the increased performance and increased cost per survivor across programs for each attack. These curves are directly related to the trend lines in the upper table and subject to the same comments. They do illustrate better than the upper curves some basic program cost and effectiveness behavior.

Consider the matter of a baseline case. In the chart, CCM must play this role although it entails 7-year costs of \$6 to \$12 per survivor. Suppose no funds were expended on nuclear preparedness, a "no civil defense" case. It would be feasible, at least in theory, to estimate the degradation of the current capability over a seven-year period, reestimate the POPDEF input parameters, and compute results for the three attacks. There would be survivors, more for Attack A than for Attack C. The percent survivors would be placed on the zero ordinate of the middle and upper charts and the dashed curves led to them. The middle chart shows most clearly that there must be an inflection point in such curves and that CCM and PPO are very nearly on that point. (To the right of the chart, in the region of higher effectiveness and higher costs, all of the attack trend lines would extend in some fashion to an imaginary point at 100 percent survivors at infinite cost per survivor.)

The foregoing discussion shows that cost per survivor is a limited measure because not all of the survivors are the result of the program investment. Some would have survived at zero program cost. It is for this reason that a "no civil defense" case is often taken as a baseline to deduct those who would survive in any event. In the lower chart of Figure 9, we have used CCM as the baseline case. Only those survivors above and beyond those estimated for CCM are credited to PPO and DRE. CCM costs are treated as sunk. CCM produces no added survivors at zero cost and 7-year costs for PPO and DRE are $150 million and $1.25 billion respectively (page 77). Cost per added survivor is plotted against percent survivors to maintain the perspective of absolute performance. If cost per added survivor were plotted against added survivors, the chart would be more dramatic but the essential relationship would have been lost. For Attack A, CCM provides 52 percent survival. Programs PPO and DRE can change the fate of the 48 percent who would be fatalities. PPO saves 17 percent of these at a cost of about $9 per added survivor. DRE saves 73 percent or over 4 times as many at a cost per added survivor less than twice that of PPO. For Attack C, CCM leaves 75 percent of the population as potential fatalities. PPO saves 8 percent of these at a cost of $12 per added survivor. DRE saves 5 times as many at a 50 percent increase in cost per survivor added.

VI. OTHER MEASURES OF EFFECTIVENESS

The purposes of this section of the report are: (a) identify those civil defense system elements and corresponding programs that contribute to broader measures of system effectiveness and whose value is only partially measured by their contribution to the reduction of casualties; and (b) explore the possible application of these broader measures of system effectiveness in DCPA program evaluation and design, as called for in the scope of work (Section I). The scope of work identifies several measures of interest; namely, reduction of long-term and genetic radiation injury, postattack control of disease and disability, maximum postattack availability of the work force, and improvement of industrial and economic recovery rates. In this section, some general considerations bearing on these broader measures of effectiveness will be discussed, preparedness program elements that contribute not only to casualty reduction but also to such measures will be identified, and practical problems of applying these measures to civil defense program design and evaluation will be addressed.

General Considerations

The fundamental effect of the adoption of a measure of effectiveness other than casualty reduction is to extend the consideration of countermeasures into the postattack or recovery period. The system elements considered in earlier sections of this report are a mix of passive countermeasures (e.g., shelter) and active countermeasures (rescue, firefighting). Postattack system elements are predominantly active countermeasures that emphasize the repair, restoration, and reconstruction of needed facilities that were damaged in one way or another during the attack. Presumably, the postattack or recovery period after a nuclear war would end, as far as the civil defense organization is concerned, when the capabilities for continued indefinite survival as a nation

have been established and acceptable institutions have become operational in the same sense that they were before the war started. This end-point, of course, goes well beyond the strict definition of civil defense in Public Law 81-920 but that fact is inherent in consideration of the measures of effectiveness cited above.

The fact that most of the casualty-reduction and postattack countermeasures are active countermeasures suggests that the most suitable measure of effectiveness of a civil defense system might be the number of healthy (uninjured) survivors remaining after attack since active countermeasures can only be conducted by healthy survivors. This consideration is evident in the framework of the Program Analysis Model described in Section IV and in Appendix B. Because the injured would require care and services on the part of the uninjured, any system that produced a high proportion of injured survivors would not be given a high effectiveness rating since the capacity to recover the necessities for continued future survival would be reduced. Thus, the first concern should be to devise that combination of system elements that would maximize the number of healthy survivors and their ratio to the injured.

The second concern would stress the means to assure continued support of the survivors to stay alive and healthy for an indefinite period of time into the future, preventing the spread of disease, malnutrition, exposure to the elements, or any other hazard that could lead to a second wave of casualties and fatalities. Thirdly, emphasis would shift to the restoration of all the facilities, institutions, and services that would provide the mix of goods and services assumed to mark the end of the recovery period.

In conceptualizing the extension of a "defense scenario", it should be noted that the postattack or recovery period begins for the people in any area at the time beyond which they are no longer required to stay in shelter as a protection against weapon effects (blast, fire, and radiation from fallout).

And because the latter would be quite variable over the landscape, the required shelter stay would be quite variable, not two weeks or any other set time period used in measuring casualty reduction.

Some areas of the country will receive no blast or fire damage and a negligible amount of fallout. People in these areas would experience no transattack phase and have no reason to stay in shelter except fear of further attack. They would be in the postattack period a day or so after the attack and could proceed to help those that need it. Because of radioactive decay, the radiologically hazardous areas will decrease in size with time and hence the "safe" areas will increase in size; this, coupled with the effect of shelter PF on exposures, provides an area-time scale of shelter emergence.

In preparation for postattack recovery, one of the first considerations would include the mobilization of the available manpower and skills that remain. To initiate this mobilization, all survivors in shelter or previously residing in the damaged areas must be relocated to centers (e.g., staging areas) in the "safe" areas. Persons evacuated from heavy fallout areas would also be brought to these centers where manpower pools could be formed from which recovery teams could be drawn. Postattack recovery measures would be conducted by the total available healthy work force drawn from the population then located, temporarily or permanently, in the vicinity of the staging area centers. At some (early) point in time, govermental institutions and agencies will need to constitute or reconstitute themselves as viable entities to assume responsibility for directing the national-to-local recovery efforts. This conceptualization is an appropriate bridge from the scenario described in Section III.

A Basic Recovery Scenario

Whatever the structure of D&C and the status of "continuity of government" is at the time, it would be most prudent that the sequence of recovery operations be organized to accomplish certain sets of tasks in about four steps. These are: (1) recover all of the essentials for immediate and near-term survival of all

persons brought into the "safe" staging area centers; (2) still relatively early in the recovery period, restore to operable condition the needed supply and distribution systems of basic utilities and services as a means of assuring survival for a still longer period; (3) restore to operable condition essential agricultural and industrial production capabilities and commercial institutions and initiate the reconstitution of social and political institutions where feasible; (4) and finally, complete the return to operation of all the needed industrial, economic, and social institutions, including a market economy, and allow the resumption of nonessential activities and institutions. A provisional listing of the most important recovery activities is given in Table 17 in the stepwise format to indicate a convenient progression of the operational functions of a conservative recovery schedule.

Although the general purpose of each item in Table 17 is implied in its statement, an expanded statement of purpose is given in Table 18, where the statements refer to the corresponding item in Table 17. These statements of general purpose are useful in conceptualizing the operations needed to carry out the functions, in identifying the system elements that would be involved in the operations, and in ascribing measures of effectiveness.

The effectiveness of a system element or countermeasure is clearly related to the purpose or purposes for which it is intended. If such individual measures can be ordered and organized with suitable and comparable effectiveness parameters that can be related to some given overall goal, the associated system element could then be assessed for effectiveness and cost as part of the overall program. The final assessment of effectiveness must be placed in an operational setting similar to that now structured in the Population Defense Model of Section III and the Program Analysis Model of Section IV. In these models, the measures of effectiveness of individual system elements are operationalized in the form of algebraic relations and

Table 17

A LISTING OF SELECTED SEQUENTIAL POSTATTACK RECOVERY FUNCTIONS

A. First Step; secure and provide survivors

(1) Food from local, regional, and national inventories or stockpiles
(2) Water for human consumption, irrigation, industry, etc.
(3) Temporary housing for homeless
(4) Clothing and bedding
(5) Fuel for cooking, heating, transport
(6) Electric power (including portable and expedient generators)
(7) Medical care of sick and injured
(8) Elementary sanitation facilities and services, waste disposal
(9) Government services, D & C, public safety service
(10) Sources of money and credit

B. Second Step; restore operation or availability of

(1) Water supply and distribution systems
(2) Electrical generating and distribution systems
(3) Telephone and other public communications systems
(4) Domestic private and commercial housing
(5) Food producing, processing, distribution, and retailing systems
(6) Fuel supply sources, processing, and distribution systems
(7) Public transport, freight transportation equipment, and network services and systems
(8) Organized work task forces; skilled and unskilled labor
(9) Hospital and nursing home systems for treatment of sick and injured
(10) Public health and sanitation facilities and services; waste disposal systems
(11) Pest and vector control
(12) Public and private social and financial services (mail, schools, churches, banks, retail outlets, service stations, garages, and so on)
(13) Welfare services, registration of survivors, finding next of kin, loans, public credit, public feeding, and so on
(14) Training for skilled and managerial employment
(15) Rationing and resource allocation systems

Table 17 (concluded)

C. Third Step; repair, construct or restore to operational condition

(1) Agricultural (food, feed, fiber, oil) production capabilities and facilities
(2) Industrial (excluding food processing) production facilities; all critical production output facilities and supporting industries
(3) Needed additional private institutions and organizations (social, commercial, business, financial)
(4) Industrial equipment and tools
(5) Industrial sources of supply; basic resources
(6) Expanded government functions at all levels
(7) Additional needed public and private housing and associated facilities
(8) System of work incentives for needed skills in work force

D. Fourth Step; reconstruct, restore, or operate

(1) All critically needed industrial, commercial, and financial institutions
(2) An equitable wage and price control system (stop rationing controls)
(3) A rationalizing market economy
(4) Warehousing and distribution centers
(5) Private transportation
(6) Amusement, sports, and recreational facilities
(7) Specialty restaurants, movies, theatres, nite clubs and so on

Table 18

GENERAL PURPOSES OF SELECTED SEQUENTIAL POSTATTACK RECOVERY FUNCTIONS

A. First Step; to assure the survivors (through salvage, collection, distribution, storage, or renovation):

(1) Food supplies sufficient for a definite period in the immediate future
(2) Water supplies sufficient for human consumption, recovery operations, operable industries, sanitation, and irrigation for a definite period in the immediate future
(3) Protection from the environmental elements
(4) Clothing and bedding supplies for comfort and protection
(5) Energy sources for cooking food, heating water, warming housing areas, and for transportation of people and supplies
(6) Adequate temporary and expedient sources of electrical power
(7) Sufficient medical supplies, facilities, and trained personnel to prevent delayed casualties, to cure or comfort the sick, and to rehabilitate the injured (purpose: to convert patients into healthy and useful people)
(8) Sufficient chemicals, equipment, and manpower to provide minimum requirements of sanitary living conditions, waste disposal capability; prevention of the proliferation of pests and vectors; prevention of epidemics and secondary casualties
(9) Continuity of responsible representative leadership and a means for providing the direction and control functions that are needed for conducting, efficiently and in a logical fashion, the follow-on recovery tasks
(10) Possibilities of a quick return to the free market form of economic system; tangible means to purchase, sell, and to enter into agreements and contracts for future business operations and enterprises

B. Second Step; to establish, or restore to operating condition facilities and functions which provide the needed capacity or capability for:

(1) Obtaining and distributing water
(2) Generating and distributing electrical energy
(3) Providing public communications
(4) Housing, more or less on a permanent basis, all survivors
(5) Obtaining, processing, distributing, and retailing foods and feed
(6) Obtaining, processing, distributing, and retailing fuels
(7) Transporting people and goods from and to any place in the nation
(8) Providing organized labor pools for use in
(a) additional recovery tasks, or
(b) the postattack operation of undamaged and repaired commercial, industrial, and social institutions

Table 18 (concluded)

(9) Providing hospital and medical care, and "home" care for the aged or the infirm
(10) Providing sanitation, waste disposal, and public health services
(11) Providing control of pests and vectors
(12) Providing social and financial services
(13) Providing welfare services
(14) Providing education, new skills to workers
(15) Controlling the prices and the consumption or use rate of limited resources

C. Third Step; to establish, restore to operational condition, or construct, facilities with the needed capacity for:

(1) Producing food, feed, fiber and oil on the farm
(2) Producing industrial goods
(3) Providing social, commercial, business, and financial services
(4) Producing equipment and tools
(5) Obtaining basic resources
(6) Providing full complement of governmental services, local, state and national
(7) Providing expanded housing, housing services
(8) Providing incentive and reward for optimum behavior

D. Fourth Step; to establish or to complete the restoration and initiate the operation of the restored facilities for:

(1) Providing industrial goods, foods, commercial services, and financial services
(2) Controlling prices and wages
(3) Providing a means for the eventual return to a market economy
(4) Providing warehousing and local distribution centers for consumer goods
(5) Reactivating the privileges of private transportation
(6) Entertaining and amusing or relaxing the population
(7) Returning to prewar life-styles, as feasible

vulnerability changes that affect casualty production. The nature and dimensions of the listing in Table 18 suggests that a comparable modeling of the postattack recovery period would be much more complex than that which suffices for consideration of casualty reduction.

Lacking a structural model comparable to POPDEF and PAM, a set of individual measures of effectiveness is offered in Table 19, in the same format as the earlier tables. The suggested measures of effectiveness are formulated in terms of recovery achievements either toward reaching a predetermined goal or toward meeting a survival deadline for disaster. The latter measure comes about because limits will exist on the available amount of survival goods relative to the number of survivors who must consume the goods to stay alive and healthy. In the earliest part of the postattack period, the goal would be to recover as large a base as possible from what is left intact for future use. There is no particular preconceived limit on the size of this base; in a heavy attack, the limit would be set by the dispersed stockpiles and inventories and the amount of useful goods that can be salvaged from damaged areas. If the means to replace these goods are not recovered before the stockpiles go to zero, starvation and other deprivations occur and cause a second wave of casualties.

The other form of measure of effectiveness is used in the second step of the recovery scenario and beyond. It is given as a ratio of the amount of production capacity restored (plus the undamaged capacity) to the total production (plus inventory) that would be needed to support the survivors indefinitely; that is, to the point where the estimated time to disaster approaches infinity. Except for the possible operation of undamaged plants and factories as soon as feasible in the postattack period, the recovery aspects for industries and commercial facilities will cease when the value

Table 19

SUGGESTED MEASURES OF EFFECTIVENESS OF SELECTED SEQUENTIAL POSTATTACK RECOVERY FUNCTIONS

A. First Step; from consumption rate allowances, demand rates, and the like with industry demands, local inventories of salvaged goods and equipment, and other hazard assessment information, evaluate:

(1) Change in the duration of survival period utilizing immediately available (local) food supplies (e.g., food in groceries and warehouses, on local farms)
(2) Change in the duration of survival period utilizing immediately available (local) water supplies (e.g., water from workable wells, rivers, undamaged sections of risk area municipal systems, hosting area water systems)
(3) Change in the ratio of available housing to the target demand for housing, by date
(4) Change in the ratio of available supplies of clothing and bedding to the demand for these items, by date
(5) Change in the duration of survival period utilizing immediately available (local) fuel supplies, distributed among various users and target demands by type of fuel
(6) Change in the ratio of available electric power from undamaged and expedient sources to postattack target demand for power (emergency levels)
(7) Change in the duration of survival period utilizing immediately available local supplies for pharmaceuticals, hospitals, staffs; increase in the number of persons added to healthy population and work force, by date; number of cases of communicable diseases cured, and the estimated frequency of cases of preventing epidemics, by date
(8) Change in the duration of survival period utilizing immediately available sanitation and waste disposal equipment and supplies (including pest and vector control materials)
(9) Change in the ratio of governmental personnel to the target demand for services by service provided, including elected officials
(10) Increase in the ratio of number of banks and other credit institutions in operation by date, and their funding capacities to the target demand for funds and credit; increase in the volume of product or cash flow by 4-digit SIC code sectors (industry, financial, retail, wholesale, and so on); increase in the ratio of wages paid for labor on recovery operations, or on output production and other econometric employment, to cost of survival goods (i.e., cost-of-survival)

Table 19 (continued)

B. Second Step; measures related to undamaged plus repaired capacities:

(1) Ratio of distributed potable water supply capacity to the target demand for water
(2) Ratio of distributed electric power supply capacity to the target demand for electricity
(3) Ratio of operating communication modes and links (or messages transmitted per day) to the target demand for communications
(4) Ratio of available houses or housing space to the target demand for houses or housing space
(5) Ratio of available food and feed sector volume capacities to the target demand for processed food (processing, wholesaling, distributing, retailing)
(6) Ratio of available fuel production and distribution capacities to the target demand for fuel
(7) Ratio of available transport capacities to the target demand for transportation (passenger, freight, by modes)
(8) Ratio of daily manpower effort on recovery tasks to the total manpower available; ratio of daily manpower effort on commercial, industrial, social tasks associated with operating facilities
(9) Ratio of available load-capacity of hospitals, clinics, and other medical care and social institutions to the target demand for medical care
(10) Ratio of available capacities of sanitation, waste disposal, and public health facilities and services to the target demand for the services
(11) Ratio of available capacities to effect control of pests and vectors to the target demand for the services
(12) Ratio of available capacities for common services to the target demand for such services
(13) Increase in the number of survivors provided welfare service by type, by date
(14) Ratio of capacity of operating training institutions to the target demand for new skills
(15) Inflation rates, disappearance rate of scarce resources, unemployment rates, percent of families on relief rolls

Table 19 (concluded)

C. Third Step; ratio of available repaired, constructed, and undamaged capacities to the target demand for:

(1) The production of food, feed, fiber, and oil seeds on farm
(2) The production of industrial (consumable) goods
(3) (New construction of) common service facilities
(4) The production of equipment and tools
(5) Basic resources
(6) Governmental services (personnel and facilities)
(7) (New construction of) housing and housing services
(8) Number of awards or pay increases made by date

D. Fourth Step

(1) Ratio of current output rates of industrial goods, foods, utilities, fuels, and the various services to the target demand for these outputs
(2) Deviation of prices and wages from target values
(3) Fraction of market goods and services eliminated from price and wage controls
(4) Ratio of available warehousing space and distribution center capacities to the target demand for these facilities
(5) Ratio of number of operating private automobiles to target allowance for private automobiles, motorcycles, and so on
(6) Ratio of capacities of amusement and similar facilities to the target demand for them
(7) Added number of leisure-time facilities operating, by type, by date

of the ratio becomes unity. Both of the postattack measure-of-effectiveness forms are directly related to the total number of people who survive, which, in turn, depends on the effectiveness of the system elements that contribute to casualty reduction.

Reduction of Long-Term Radiation Effects

The long-term effects of radiation injury take the form of statistical increases in the incidence of late-appearing cancers, leukemia and other disorders, and general life-shortening. The time scale of these effects is such that they have little direct connection with the postattack recovery process outlined above; that is, they appear much later in what are otherwise uninjured healthy survivors. Similarly, the genetic effects of radiation injury appear in a statistical sense in subsequent generations.

The relative incidence of long-term and genetic radiation injury effects are generally considered to be proportional to the total exposure of a population in a statistical sense. Therefore, all actions and measures that contribute to decreasing the total exposure of people also contribute to the reduction of the long-term and genetic radiation injury of the population. Shielding provided by good fallout shelter is the main method of protecting against both short-term casualties and long-term radiation effects. Additionally, RADEF support that permits best use of the shelter potential, water and ventilation provisions that avoid premature shelter leaving, and remedial radiological measures also contribute to both measures. However, the reduction of long-term and genetic radiation injury poses more severe requirements than the avoidance of fatalities and short-term radiation sickness. For example, the existence of high-grade radiological shelter, such as shelter categories "A" and "B/C", plays an important role in the reduction of long-term effects and genetic damage although it does not contribute as much to the casualty

reduction measure of effectiveness for the persons located in the "excessively good" shelter. Similarly, adopting a fallout protective posture that raises the rated protection factor of the B/C shelter from 500 to 875 has little impact on casualty reduction but can have a substantial effect on reduction of the total population exposure.

Some activities in the defense scenario that require out-of-shelter operations in a fallout area (fire fighting, rescuing, decontaminating, and the like) will increase the exposure of the persons that are involved in these operations. Certain effects, such as genetic injury, can be avoided if persons beyond normal reproductive ages perform these tasks. Otherwise, rigorous exposure control measures during outside operations can avoid prompt casualties and the operations may contribute to reduction of long-term effects if the bulk of the population is allowed to remain sheltered.

A practical difficulty in applying this measure of effectiveness to DCPA program design and evaluation is that long-term and genetic radiation injury is related to the total radiation exposure whereas the TENOS model and hence, POPDEF are based on an attack environment model that computes ERD. The entire computational procedure would have to be restructured to produce total exposures in lieu of ERD. Techniques exist for tracing the radiation exposure of population groups[9,10] and no insurmountable difficulties are in prospect, but the computational program would be quite distinct from the current DCPA models.

A more fundamental problem is that the objective of minimizing long-term and genetic radiation effects runs counter to the objective of the other suggested measures of effectiveness, especially that of improvement of industrial and economic recovery rates. The same "excessively good" shelters that could contribute to reduction of long-term effects would permit both earlier and longer periods of outside operation during the early period following attack.

Actually, the time that can be spent out of shelter increases roughly in proportion to the amount that the shelter PF exceeds the minimum PF required to prevent casualties or some other radiological response of the occupants. The advantage of this possibility is earlier restoration of vital facilities, earlier production of essential survival supplies, and the like.

Under proper control within the designated exposure limits for no acute effects of radiation,[11] use of all the allowed exposure by planned outside operations would lead to long-term radiation effects as anticipated for anyone receiving the exposure either as an occupant of a marginal shelter or as an occupant of a high-grade shelter with controlled additional exposure from outside operations. But, since the latter would be controlled exposures, the number, age, sex, and skills of the workers could be judiciously selected, relative to survival needs, to produce a minimum impact on later recovery operations and medical problems. Nonetheless, the objective of keeping the total exposure of all the survivors as low as possible will often be counter to that of continued survival and recovery of society as a whole. Thus, one of the main tasks of leadership (D&C) would be to make decisions regarding the relative risks to be taken among competing objectives. The same decisions must be addressed in the design and evaluation of civil defense programs.

Other Measures of Effectiveness

In a real sense, the objectives of postattack control of disease and disability and of maximum postattack availability of the work force are subsumed within the objective of societal recovery, as can be seen from a survey of Table 19. Perhaps the largest factor affecting industrial and economic recovery rates is the available work force to assign to the tasks. The other major factors are the residual capacities surviving as affected by preattack blast and thermal hardening techniques and dispersal of inventories, equipment, and plants to hosting areas. These, besides the form of attack, will determine the base from which to complete the necessary recovery effort.

In turn, all elements that operate to reduce casualties also operate to increase the work force. Also included are those measures that prevent or cure postattack illness, keep the survivors housed, fed, and healthy, and that provide the means to remain so indefinitely. System elements dealing with postattack diseases and injuries tend to include a range of measures: maximizing the number of healthy survivors relative to the sick and injured; enlarging the capabilities for treating more people and returning them to a healthy status as rapidly as possible; and doing what is necessary to prevent the spread of contagious diseases.

Thus, all of the preparedness elements outlined in Appendix A that contribute to the reduction of casualties also contribute to broader measures of effectiveness and are only partially evaluated by their contribution to the reduction of casualties. Moreover, many attributes of these elements may contribute more to the broader measures than they do to casualty reduction. Some examples have been alluded to: high-grade fallout shelter, availability of water and ventilation, decontamination, and survivable D&C among others. At the same time, a number of system elements included in Appendix A are found not to contribute to casualty reduction, at least at the current stage of development of PAM and POPDEF. These include not only the obvious measures to protect industry and agriculture and the medical care measures discussed in Section III but also such elements as food and medical stocks (SM and SN), public health measures to control disease and vectors (MC and MD), and certain resource service functions, such as supplying goods (RB) and repairing facilities (RI). Although some of these elements may be found to contribute in some way to casualty reduction, it is likely that most of them must be justified by appealing to a broader measure of system effectiveness.

The practical difficulties in adopting these broad measures of effectiveness as a basis for civil defense program design and evaluation are considerable. The mere listing of the individual measures of effectiveness in Table 19 reveals the need for a host of analytical procedures, models, and techniques for making the suggested evaluations. The listing also suggests that many additional outputs would be required from the damage assessment system and that the required data bases for such assessments may be limited or non-existent. Of course, similar limitations of knowledge and data exist for POPDEF and PAM as they are currently constituted. Yet the model formulation appears useful not only as a tool for civil defense program analysis but also as a tool for assessing technical and operational knowledge and data and for defining in an operational context the nature of research and data collection needed for this kind of analysis. The latter use is likely to be a beneficial result of attempts to extend the analysis to include other measures of system effectiveness.

It would appear useful to consider the matter of industrial and economic recovery rates separately from the matters of postattack control of disease and disability and availability of the work force. The latter seem to lend themselves to an analytical approach based on an extension of the POPDEF defense scenario into the postattack period, with corresponding expansion of the Program Analysis Model to generate estimates of the needed additional input parameters. The calculation would continue to trace the fate of uninjured and injured survivors through all or most of steps 1 and 2 of Table 17. Societal recovery, on the other hand, has been found to demand the use of other techniques, including input-output and linear programming models of supply, demand, consumption, and investment relationships. A full assessment of civil defense programs as measured by recovery rates is likely to result from interfacing the population survival aspects with the best of the economic recovery models.

VII. SUMMARY AND RECOMMENDATIONS

Summary

A methodology has been developed for estimating the individual and combined effectiveness of the important elements of the civil defense operating system and the corresponding elements of the preparedness program, as measured by population survival. All system elements that contribute to the reduction of casualties in a significant way have been incorporated in the analysis and implemented, with the exception of medical care, which could be implemented if the necessary input data were available. The methodology consists of two related models of civil defense activities: the Population Defense Model (POPDEF), which assesses fatalities and injuries under nuclear attack, and the Program Analysis Model (PAM), which uses data and estimates of the product of specific program elements to generate most of the inputs to POPDEF. The use of other measures of effectiveness has been explored.

The Population Defense Model has been implemented at the DCPA Computer Center and used to estimate the casualties associated with three potential civil defense programs under three hypothetical nuclear attacks. POPDEF employs a defense scenario technique to model changes in the vulnerability of the population and to assess casualties. It operates on three regions -- Risk, Host, and Neither -- using data provided by the TENOS model.

The Program Analysis Model identifies relationships among elements of civil defense and defines paths through these relationships along which quantitative descriptions of the preparedness program can be translated into estimates of the POPDEF input parameters. To provide a structure for PAM, civil defense program elements have been organized and defined. Relationships among these elements are defined by means of a systems algebra. The result is a set of system trees in which quantitative estimates of the product of preparedness program elements can be used to generate estimates of key POPDEF input parameters. The two models together allow a detailed program description and changes in any of its elements to be reflected in terms of casualty reduction.

Example calculational results are presented in Table 20 for three programs and three hypothetical attacks. The programs are Program D Prime, a program that maintains the current civil defense capability, and a program that adds to current capability only a crisis relocation planning effort. Of the three attacks, the first two are major attacks aimed at military and urban-industrial targets. The third, Attack C, is a heavy attack that adds a population-oriented attack against relocation concentrations. The PAM and POPDEF estimates used in these calculations were estimated by the DCPA professional staff.

The exploration of the application of measures of effectiveness other than casualty reduction suggests that the effect is to extend the consideration of countermeasures and hence, the defense scenario into the postattack or recovery period. In lieu of such extension, the analysis concludes that it would be desirable to evaluate candidate civil defense programs on the basis of uninjured survivors and their ratio to the injured.

Recommendations

Based on the work performed under Contract No. DCPA01-77-C-0223, the following recommendations are made:

1. The Population Defense Model (POPDEF) now implemented at the DCPA Computer Center should be adopted as the interim method of casualty assessment for program evaluation and other studies.

2. Research should be undertaken to derive appropriate fatality functions that could be used to represent the effect of various levels of medical care, thus permitting its inclusion in the defense scenario.

3. In program evaluation and design, emphasis should be placed on the number of uninjured survivors and their ratio to the injured rather than on total survivors, so as to maximize the contribution of population preparedness to societal recovery.

Table 20

EXAMPLE ASSESSMENT RESULTS*

Program	Attack A	Attack B	Attack C
D Prime			
Percent Survivors	87%	74%	57%
Percent Uninjured Survivors	80	63	45
Current Capability			
Percent Survivors	52	39	25
Percent Uninjured Survivors	38	25	16
Current Capability Plus Relocation Plans Only			
Percent Survivors	60	46	31
Percent Uninjured Survivors	47%	31%	21%

* All values in terms of percent of the U.S. population.

4. The Program Analysis Model (PAM) contained in Appendix B should be reviewed and adopted as the interim method for assessing the contribution of program elements to casualty reduction.

5. The system element structure exhibited in Table 9 and defined in Appendix A should be reviewed and adopted as a basis for program analysis in conjunction with the Program Analysis Model. This structure should be considered as a basis for program description and costing.

6. The Program Analysis Model, the Population Defense Model, and the supporting elements of the TENOS model should be considered for use as a tool in defining research needs and data-gathering requirements. Sensitivity analyses should be accomplished in connection with this use to aid in establishing priorities.

7. The methodology should be considered for use in defining the required content of plans and exercises, training, and emergency public information materials, as well as for use in orienting and training civil defense officials in civil defense management and direction and control functions.

8. A formal procedure should be developed for periodic review and upgrading of all aspects of the program evaluation and design methodology.

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Appendix A

ELEMENTS OF CIVIL DEFENSE

Appendix A

ELEMENTS OF CIVIL DEFENSE

CONTENTS

Appendix A

ELEMENTS OF CIVIL DEFENSE

In developing the structure of the Program Analysis Model (PAM), considerable difficulty was experienced in attempting to maintain the traditional differences between the preparedness system and the operating system. Therefore, the two were combined and a new structure suited to the needs of PAM was developed.

For this the civil defense program is defined in two ways:

- Program Activities: the ways in which funds are expended in achieving the desired operating capabilities: planning, procurement, and staffing.
- Program Elements: the categories of preparedness programming -- Radiological Defense, Emergency Public Information, etc. -- that produce operating capabilities for the operating system.

These are as two sides of the same coin. The elements describe what is to be obtained or achieved by the preparedness program. The activities describe what is to be done in the preparedness program elements to accomplish their purposes. Thus, each program element contains one or more of the program activities.

Program Activities

Each countermeasure in civil defense operations is accomplished by a part of the operating system that is in itself a system; i.e., a group of related things functioning together under control to produce a desired result. Each alternative preparedness program is dedicated to achieving a desired operating capability for selected countermeasure systems and for combinations of them.

All of the systems required for the countermeasures that constitute civil defense operations must have both hardware and personnel. That is, (1) none of the countermeasures can be accomplished solely by human activity, and (2) none of the countermeasure systems can function without human intervention. Therefore, each must have the following:

a. Hardware: facilities, equipment, and materials.

b. Personnel: people trained to perform system operations under system direction and control.

c. Services: operations performed for civil defense by others who are not part of the civil defense system.

In order that these things may function together to produce the desired result, each operating system must also have:

d. Operations Plans: specifications of how the hardware, personnel, and services are related (organization and staffing) and how they function together and are directed and controlled (procedures).

To produce the desired operating capability, the preparedness system must have a functional capability of its own and this in turn requires hardware, personnel, services, and operations plans just as the operating system does. Sometimes the cost of these things can be identified with a particular program element and in such case the preparedness system item description is included with the operating system item. When the preparedness system costs cannot be specifically identified with one operating system item, they are included in the Program Management program element.

It follows, then, that a complete description of each program element should address each of the following activities either by specific description of what is included or by specific exclusion.

1. Planning: of two kinds:

a. Program: study, design, evaluation of alternatives, and preparation of action documents for such preparedness actions as budgets, schedules, and so on.

b. Emergency Operations: study, design, evaluation of alternatives, preparation, and publication of emergency operations plans including organization, staffing, and information plans, and standing operating procedures.

2. Procurement: of hardware and services, either through the expenditure of funds or through the concluding of arrangements for the purpose without an expenditure of funds.

a. Facilities: preliminary study, design, construction, alteration, and maintenance of buildings and other structures, including the installation of mechanical and electrical equipment necessary for use of the facility for its intended purpose but not for the processes to be conducted in the facility.

b. Equipment: design, purchase, transportation, storage, installation, testing, and maintenance of non-expendable equipment necessary for the conduct of processes.

c. Materials: design, purchase, transportation, storage, final delivery, and maintenance of expendable goods including data.

d. Services: design, purchase, and testing of services.

3. Staffing: of two kinds:

a. Recruiting: enrolling of people for emergency operating staffs including payment of salaries or honoraria to such people as inducements to remain enrolled.

b. Training: course instruction of individuals for positions in emergency operating staffs and of instructors for them; exercise of staffs in emergency operations for training; and preparation and publication of course and exercise materials.

For convenience of reference, Table 9 of the report is reproduced here as Table A-1, followed by the definitions of the elements.

Table A-1

SYSTEM ELEMENT STRUCTURE FOR PROGRAM ANALYSIS MODEL

Major Element	Subordinate Elements	Element Code
Shelter	Survey	SA
	Marking	SB
	Planning	-
	Community Shelter	SC
	Crisis Relocation Shelter	SD
	Shelter Production	SE
	Production	-
	Single Purpose	SF
	Slanting	SG
	Upgrading	SH
	Expedient	SI
	Ventilation	SJ
	Stocking	-
	Water	SK
	Sanitation	SL
	Food	SM
	Medical	SN
	Communications	SR
	Public (EBS)	SO
	System	SP
Crisis Relocation Planning (CRP)	Relocation Movement	XA
	Reception and Care	XB
	Revising Supply Channels	XC
	Commuting Essential Workers	XD
Warning	Increased Capability	-
	National System	AC
	Alerting	AA
	Informing	AB
	Local System	AF
	Alerting	AD
	Informing	AE
	Reduced Delay	-
	National System	AI
	Alerting	AG
	Informing	AH
	Local System	AL
	Alerting	AJ
	Informing	AK

Table A-1 (Continued)

Major Element	Subordinate Elements	Element Code
Radiological Defense (RADEF)	Shelter RADEF	US
	Instruments	UA
	Monitors	UB
	Self-Help RADEF	UH
	Instruments	UC
	Monitors	UD
	Area RADEF	UW
	Instruments	UE
	Monitors	UF
	RADEF Officers	UG
Emergency Public Information (EPI)	Information Preparations	-
	Self-Help	IA
	Warning	IB
	Relocation	IC
	Shelter	ID
	Broadcast Station Protection	IE
Emergency Services		-
Fire Service	Public Preparedness	-
	Self-Help	FA
	Warning	FB
	Relocation	FC
	Shelter	FD
	Fire Prevention	-
	Self-Help	FE
	Fire Service	FF
	Fire Suppression	FG
	Rescue	FH
	Inform D&C	FI
Medical Service	Public Health	-
	Self-Help Sanitation	MA
	Medical Service Sanitation	MB
	Controlling Disease	MC
	Controlling Vectors	MD
	Medical Care	-
	Transporting	ME
	Self-Help First Aid	MF
	Service First Aid	MG
	Facility Treatment	MH
	Inform D&C	MI

Table A-1 (Continued)

Major Element	Subordinate Elements	Element Code
Police Service	Public Preparedness	-
	Self-Help	LA
	Warning	LB
	Relocation	LC
	Shelter	LD
	Maintaining Order	-
	Facilities	LE
	Relocation Traffic	LF
	Movement to Shelter	LG
	Remedial Movement	LH
	Suppressing Crime	-
	Controlling Access	LI
	Controlling Criminals	LJ
	Warning	LK
	Inform D&C	LL
Warden Service	Public Preparedness	-
	Self-Help	WA
	Warning	WB
	Relocation	WC
	Shelter	WD
	Managing Movement	-
	Relocation	WE
	To Shelter	WF
	Remedial	WG
	Shelter-Based Operations	-
	Fire Fighting	WH
	Rescue	WI
	Remedial Movement	WJ
	Managing Shelters	-
	Public Information	WK
	Improve Blast Posture	WL
	Improve Fallout Posture	WM
	Operate Ventilation	WN
	Control Water Use	WO
	Shelter RADEF	WF
	Sanitation	WR
	Medical Care	WS
	Feeding	WT
	Reception and Care	WX
	Lodging	WU
	Feeding	WV
	Welfare Services	WW
	Warning	WY
	Inform D&C	WZ

Table A-1 (Continued)

Major Element	Subordinate Elements	Element Code
Resource Service	Supply	-
	Revising Supply Channels	RA
	Supplying Goods	RB
	Transporting	-
	Relocation of People	RC
	Commuting Workers	RD
	Remedial Movement	RE
	Goods	RF
	Facilities	RJ
	Establishing	RG
	Operating	RH
	Maintaining & Repairing	RI
	Clearing Debris	RM
	Roads	RK
	Buildings	RL
	Decontaminating	RP
	Buildings	RN
	Terrain	RO
	Inform D&C	RR
Protect Industry	Hardening	-
	Facilities	BA
	Equipment	BB
	Inventories	BC
	Emergency Shut Down	-
	Facilities	BD
	Processes	BE
Protect Agriculture	Public Preparedness	-
	Self-Help	GA
	Shelter	GB
	Protect Livestock	-
	Protection	GC
	Feeding	GD
	Protect Crops	-
	Protect Seed Stock	GE
	Decontamination	GF
Direction and Control Federal D&C	Support State and Local	-
	Goods	DA
	Services	DB
	Information	DC
	Informing the Public	DD
	Warning the Public	DG
	Alerting	DE
	Informing	DF

Table A-1 (Continued)

Major Element	Subordinate Elements	Element Code
State D&C	Support Local	-
	Goods	DH
	Services	DI
	Information	DJ
	Inform Federal	DK
Local D&C	Public Preparedness	-
	Self-Help	DL
	Warning	DM
	Relocation	DN
	Shelter	DO
	Warning the Public	DR
	Alerting	DP
	Informing	DQ
	Informing the Public	DS
	Informing the System	DZ
	State	DT
	Fire Service	DU
	Medical Service	DV
	Police Service	DW
	Warden Service	DX
	Resource Service	DY
Research and Development		KA
Federal Program Management	Planning	-
	Program	HA
	Operational	HB
	Procurement	-
	Facilities	HC
	Equipment	HD
	Materials	HE
	Services	HF
	Staffing	-
	Recruiting	HG
	Course Instruction	HH
	Organization Exercise	HI
	Supporting State and Local	-
	Funds	HJ
	Assistance	HK
	Information	HL
	Administration	HM

Table A-1 (Concluded)

Major Element	Subordinate Element	Element Code
State Program Management	Planning	-
	Program	NA
	Operational	NB
	Procurement	-
	Facilities	NC
	Equipment	ND
	Materials	NE
	Services	NF
	Staffing	-
	Recruiting	NG
	Course Instruction	NH
	Organization Exercise	NI
	Supporting Local	-
	Funds	NJ
	Assistance	NK
	Information	NL
	Inform Federal	NM
	Administration	NN
Local Program Management	Planning	-
	Program	PA
	Operational	PB
	Procurement	-
	Facilities	PC
	Equipment	PD
	Materials	PE
	Services	PF
	Staffing	-
	Recruiting	PG
	Course Instruction	PH
	Organization Exercise	PI
	Inform State	PJ
	Administration	PK

Program Elements

The definitions given below relate to the headings in Table A-1. The complete description of each of these elements would contain references to all of the program activities defined above, specifying those that require action and specifically excluding those that do not.

SHELTER

Providing capabilities to (1) shield people against attack effects, (2) maintain a viable environment for occupants of the shelters, and (3) conduct such in-shelter operations as will minimize the effects of attack on these occupants, including the following subordinate elements:

Shelter Survey - SA: Examining the physical characteristics of existing facilities, comparing these characteristics to established standards, and determining (1) their suitability for use as shelter and (2) their capacities in allowable number of occupants, all as a basis for shelter planning.

Shelter Marking - SB: Identifying the facilities and the public shelter spaces within them, as selected in shelter planning, in order to expedite the entering of shelter when the need arises.

Shelter Planning: Providing plans (both program and operations) for achieving a capability to protect people in shelter by (1) selecting existing facilities for use as shelter and (2) providing other facilities for use as shelter, including the following types of planning:

Community Shelter - SC: Preparing plans for providing shelter facilities in the near vicinity of the normal locations of the population by specifying (1) the existing facilities to be used, (2) the types and locations of additional facilities to be procured or produced, and (3) the allocation of population to shelters as a basis for operations plans and emergency public information.

Crisis Relocation Shelter - SD: Preparing plans for providing shelter facilities in areas to which people would be relocated in a crisis by specifying (1) the existing facilities to be used, (2) the types and locations of additional facilities to be procured or produced, and (3) allocation of population to shelter as a basis for operations plans and emergency public information.

Shelter Production - SE: Preparing plans for procuring or producing additional shelter facilities including (1) establishing standards, (2) preparing typical construction plans and specifications, (3) specifying types of shelters to be procured or produced and their locations, and (4) preparation of plans for procuring the specified facilities by whatever means are appropriate.

Shelter Production: Procuring the additional facilities specified in Shelter Production Planning (SE) in the following ways:

Single Purpose Shelter - SF: Preparing plans and specifications and constructing facilities for the sole purpose of using them as shelters.

Shelter Slanting - SG: Modifying the plans and/or specifications of facilities to be constructed for other purposes and procuring the construction of these facilities in accordance with the modified plans and/or specifications in order to render them, in whole or in part, suitable for use as shelters.

Shelter Upgrading - SH: Preparing plans and specifications and constructing alterations to existing facilities so as to render them, in whole or in part, suitable for use as shelters.

Expedient Shelter - SI: Preparing plans and specifications and constructing facilities intended to have a short useful life to be used as shelters.

<u>Shelter Ventilation - SJ</u>: Providing the capability to maintain safe levels of temperature and humidity for occupants of the shelters specified for use in Community Shelter (SC) and Crisis Relocation Shelter (SD) plans.

<u>Shelter Stocking</u>: Procuring and placing items necessary for extended occupancy of the shelters specified for use in Community Shelter (SC) and Crisis Relocation Shelter (SD) plans, of the following classes:

Water - SK: Storage containers for specified amounts of potable water (to be filled contingent on a decision to fill them) plus cups for the supply of water for drinking by shelter occupants.

Sanitation - SL: Specified materials for personal hygiene and containers for bodily wastes and refuse.

Food - SM: Specified amounts of food for shelter occupants.

Medical - SN: Specified amounts of medical items needed to treat illnesses and injuries.

<u>Shelter Communications - SR</u>: Providing the capabilities in the shelters for communications between D&C and the shelter of two kinds:

Public - SO: Means for receiving information, guidance, and instructions intended for the public and broadcast by D&C over the Emergency Broadcast System.

System - SP: Means for (a) receiving information, guidance, and instructions from D&C intended for system personnel and (b) transmitting situation information to D&C, both over whatever communications channels are established.

CRISIS RELOCATION PLANNING

Providing plans for relocating people from higher risk areas, for caring for them while relocated, and for continuing essential activities in the risk areas, to include the following subordinate elements:

Relocation Movement Planning - XA: Preparing plans for the movement of people away from risk areas including (1) specifying the host areas to be assigned to each risk area, (2) specifying the routes to be used in the movement, and (3) specifying the equipment and goods to be moved in the relocation.

Reception and Care Planning - XB: Preparing plans for lodging, feeding, and providing welfare and other services in host areas for relocated people including (1) surveying of existing facilities, (2) specifying those to be used and their purposes, and (3) assigning lodging to defined groups if deemed appropriate.

Revising Supply Channels - XC: Preparing plans for revising the channels of supply of essential goods and services to fit the changed demand pattern resulting from the relocation of the population.

Commuting Essential Workers - XD: Preparing plans for providing transportation between risk and host areas for workers who will be required to continue essential activities in the risk areas.

WARNING

Providing capabilities to alert and inform the population of (1) an impending attack and (2) the necessity of taking immediate protective action, including the following subordinate elements:

Increased Warning Capability: Providing improved means to warn the public by (1) increasing the number of people who can receive the warning message, (2) increasing the clarity of the message, or (3) doing both. These improvements can be achieved either alternatively or jointly in the following ways:

National System - AC:

Alerting - AA: Means to activate the alerting signal directly from the National Warning Center (Federal D&C) or to supply warning information to local D&C.

Informing - AB: Means to activate the local broadcast of a verbal warning message directly from the National Warning Center.

Local System - AF:

Alerting - AD: Means to activate the alerting signal from Local D&C upon receipt of information from the National Warning Center.

Informing - AE: Means to give the warning message by (a) the alerting signal or (b) activation of the local broadcast of a verbal message.

Reduced Delay: Providing improved means to increase the speed with which the warning message is delivered to and understood by the public and thus reduce the delay between detection of the attack and response to the warning by the public. These improvements can be achieved either alternatively or jointly in two ways:

National System - AI:

Alerting - AG: Means to increase the speed with which warning information is (a) initiated in the National Warning Center, (b) distributed through the system directly to broadcast stations, or (c) distributed through the system to local warning points.

Informing - AH: Means to reduce the delay in broadcast stations between receipt of the warning information from the National Warning Center and initiation of the broadcast.

Local System - AL:

Means to reduce the delay:

(a) In local D&C between receiving the warning information from the National Warning Center and (1) activating the local alerting signal (AJ) and (2) informing the local broadcast station.

(b) Between receiving the information in the broadcast station and initiating the broadcast (AK).

RADIOLOGICAL DEFENSE

Providing capabilities to (1) identify and measure fallout radiation, (2) assemble and analyze the available data, and (3) advise as to the implications of fallout radiation including the following:

Shelter RADEF - US: Providing capabilities to measure, interpret, and advise as to the implications of radiation within shelters including: supplying instruments (UA) and recruiting and training Monitors (UB).

Self-Help RADEF - UH: Providing capabilities to measure, interpret, and advise as to the implications of radiation in the areas in which emergency operations are being conducted and in facilities and places within radiation fields where activities must be carried on including: supplying instruments (UC) and recruiting and training Monitors (UD).

Area RADEF - UW: Providing capabilities to measure, interpret, and advise as to the implications of radiation throughout the area in which the Area RADEF system is deployed to assist D&C in directing and controlling emergency operations and in informing the emergency services and the public including: supplying instruments (UE) and recruiting and training Monitors (UF) and Radiological Defense Officers and their assistants (UG).

EMERGENCY PUBLIC INFORMATION

Providing an assured capability to communicate information from governments to the public in an emergency, including the following subordinate elements:

Information Preparations: Providing the capabilities to inform the public by supplying informational materials and by concluding necessary arrangements for the dissemination, either through the media or by direct means, of information of the following types:

Self-Help - IA: Information related to activities suitable for the public, to mitigate and alleviate the effects of attack in such matters as home shelter, fire prevention, sanitation, first aid, rescue, and so on.

Warning - IB: Information related to the nature and meaning of the alerting signal and confirming message , the means by which they will be transmitted, and the appropriate response.

Relocation - IC: Information related to crisis relocation including (a) location of assigned host areas; (b) plans and preparations for reception, care, and sheltering in the host areas; and (c) details of the movement plan with specific emphasis on actions the public must take.

Shelter - ID: Information related to occupation of the shelters including (a) locations of the shelters, (b) preparations the public should make in advance of going to shelter, (c) conditions they can expect to find in the shelters, (d) the specific actions they should take in moving to shelter, and (e) the actions they should take (1) to obtain the maximum protection in the shelters and (2) to conduct fire fighting, rescue, remedial movement, and so on.

Broadcast Station Protection - IE: Providing the capabilities to protect people and equipment and to supply emergency power necessary for assuring continued ability of specified broadcast stations to operate in an emergency.

EMERGENCY SERVICES

Providing the special capabilities necessary to enable government forces (e.g., fire, police, public works) and public service organizations (e.g., utilities, hospitals) to perform civil defense emergency operations under civil defense system direction and control, including the following:

FIRE SERVICE

Providing the necessary capabilities for (1) participating in informing the public and (2) employing professional skills in preventing and suppressing fire and in rescuing trapped people, as follows:

Public Preparedness: Providing the capabilities to employ the EPI materials and other information related to fire fighting and rescue so that the public may be informed about Self Help (FA), Warning (FB), Relocation (FC) and Shelter (FD).

Fire Prevention: Providing the capabilities to prevent fires that would result either from weapons effects or from other causes, such as leaving buildings unattended, by means of:

Self Help - FE: Actions taken by the public as a result of information provided in Public Preparedness efforts.

Service - FF: Actions taken by the fire service in organized, professional efforts to reduce the potential for ignitions and fire starts.

Fire Suppression - FG: Providing the capabilities necessary for organized, professional efforts to suppress fires resulting from weapon effects and from other causes, such as leaving buildings unattended.

Rescue - FH: Providing the capabilities necessary for organized, professional efforts to release people trapped by debris resulting from attack effects.

Inform D&C - FI: Providing the capabilities to inform Direction and Control as to the current situation with respect to attack effects, condition of the fire service, and so on.

MEDICAL SERVICE

Providing the necessary capabilities for (1) participating in informing the public and (2) employing professional skills in maintaining public health and in giving medical care, as follows:

Public Health: Providing the capabilities necessary to maintain the health of the public and inhibit the spread of disease to those who are well, as follows:

Sanitation: Providing the capabilities necessary for maintaining a sanitary environment including the collection and disposal of refuse, garbage, and sanitary sewage, and the maintenance of the purity of water supplies by means of:

Self Help - MA: Actions taken by the public as a result of information provided in Public Preparedness efforts.

Service - MB: Actions taken by the medical service in organized, professional efforts to maintain a sanitary environment.

Controlling Disease - MC: Providing the capabilities to prevent the spread of disease from those who have, or may carry, it to those who are susceptible to it.

Controlling Vectors - MD: Providing the capabilities to limit the number of organisms that carry disease-producing agents.

Medical Care: Providing the capabilities to supply medical care to the ill and injured and other care (such as pre-natal) including the transporting of patients to medical care facilities, as follows:

Transporting Ill and Injured - ME: Providing the capabilities to transport ill and injured to places where medical care is available and to provide necessary medical care while *en route*.

First Aid: Providing the capabilities to treat minor illnesses and injuries not requiring facility treatment, by means of:

Self Help - MF: Actions taken by the public as a result of information provided in Public Preparedness efforts.

Service - MG: Actions taken by the medical service in organized professional (or semi-professional) efforts to supply "first aid" medical care.

Facility Treatment: Providing the capabilities to supply medical care of illness and injury in treatment centers, clinics, hospitals, and so on established for the purpose.

Inform D&C - MI: Providing the capabilities to inform Direction and Control as to the current situation with respect to attack effects, condition of the people, facility capacities, conditions of the medical service, and so on.

POLICE SERVICE

Providing the necessary capabilities for (1) participating in informing the public, (2) maintaining order where emergency operations are being performed, (3) controlling traffic in movements of the public, (4) suppressing crime, and (5) warning the people, as follows:

Public Preparedness: Providing the capabilities to employ the EPI materials and other information related to maintaining order and controlling traffic and access so that the public may be informed about Self Help (LA), Warning (LB), Relocation (LC), and Shelter (LD).

Maintaining Order: Providing the capabilities to maintain order where emergency operations are being performed including the controlling and guiding of public movements, as follows:

Maintaining Facility Order (LE): Providing the capabilities to maintain order in facilities where emergency operations (feeding, medical care, etc.) are being performed.

Controlling Relocation Traffic - LF: Providing the capabilities for controlling traffic in a crisis relocation movement.

Controlling Movement to Shelter - LG: Providing the capabilities for controlling (guiding) a movement to shelter.

Controlling Remedial Movement - LH: Providing the capabilities for controlling (guiding) an organized remedial movement.

Suppressing Crime: Providing the capabilities for suppressing crime by controlling access to areas and facilities and by controlling criminals, as follows:

Controlling Access - LI: Actions to prohibit the access of unauthorized persons to areas or to facilities in order to prevent criminal loss of property, public or private.

Controlling Criminals - LJ: Actions to restrain the activities of criminals including the operation of detention facilities.

Warning - LK: Providing the capabilities for the police service to warn the people supplementing the warning system.

Inform D&C - LL: Providing the capabilities to inform Direction and Control as to the current situation with respect to attack effects, conditions of the police service, and so on.

WARDEN SERVICE*

Providing the necessary capabilities for (1) participating in informing the public,(2) managing public movements, (3) conducting operations outside the shelters employing shelter occupants, (4) managing shelters, (5) conducting reception and care activities, and (6) warning the people as follows:

Public Preparedness: Providing the capabilities to employ the EPI materials and other information so that the public may be informed about Self Help (WA), Warning (WB), Relocation (WC), and Shelter (WD).

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* While current doctrine does not envision a "Warden Service", there are a number of civil defense functions not now assigned to a service that would best be managed by an emergency service.

Managing Movement: Providing the capabilities to manage movements of the public (1) in Crisis Relocation (WE), (2) to Shelter (WF), and in organized Remedial Movement (WG).

Shelter-Based Operations: Providing the capabilities to conduct operations outside the shelters employing the capabilities available in the shelters, in the areas of Fire Fighting (WH), Rescue (WI), and Remedial Movement (WJ).

Managing Shelters: Providing the capabilities to manage and conduct in-shelter operations, as follows:

Public Information - WK: Informing shelter occupants on the attack situation, desirable protective actions, and so on.

Improve Blast Posture - WL: Improving the protection afforded by the shelter against direct weapon effects by controlling the arrangement of the occupants within the available spaces.

Improve Fallout Posture - WM: Improving the protection afforded by the shelter against fallout effects by controlling the use of the available spaces and the arrangement of the occupants within them.

Operate Ventilation - WN: Managing the ventilation of the shelter so as to prevent or delay the occurrence of excessive effective temperature by (1) directing the assembly and operation of ventilation equipment and (2) controlling the opening and closing of doors and windows to enhance natural ventilation.

Control Water Use - WO: Managing the use and cleanliness of available water supplies so as to prevent or delay the possible occurrence of hazardous dehydration of the shelter occupants and so as to inhibit spread of disease.

Shelter RADEF - WF: Using instruments available in the shelter, and reading and interpreting the data, in lieu of, or in addition to, the efforts of trained monitor(s) occupying the shelter.

Sanitation - WR: Managing activities to maintain a sanitary environment within the shelter.

Medical Care - WS: Managing first aid activities within the shelter and arranging for medical care of those needing more than first aid.

Feeding - WT: Managing the feeding of shelter occupants and controlling the use and cleanliness of shelter food stocks.

Reception and Care - WX: Providing the capabilities to lodge, feed, and supply welfare service to people displaced from their home because of relocation or because of the effects of attack, as follows:

Lodging - WU: Assigning and managing temporary lodging for displaced people.

Feeding - WV: Supplying, preparing, and serving food to displaced people.

Welfare Services - WW: Supplying material aid and counsel for displaced people.

Warning - WY: Providing the capabilities for the warden service to warn the people, supplementing the warning system.

Inform D&C - WZ: Providing the capabilities for the warden service to inform Direction and Control as to the current situation with respect to attack effects, condition of the shelters and their occupants, and so on.

RESOURCE SERVICE

Providing the necessary capabilities for (1) supplying goods, (2) transporting people and goods, (3) supplying facilities, (4) clearing debris, and (5) decontaminating, as follows:

<u>Supply</u>: Providing the capabilities for assuring the availability of essential goods and distributing them as required, through:

Revising Supply Channels - RA: Actions to achieve the revision of the normal channels of supply of essential goods and services as planned in Crisis Relocation Planning (Revising Supply Channels - XC) including (1) informing the suppliers as to the relocated distribution of the public and (2) assisting the suppliers in achieving and maintaining the revised supply channels.

Supplying Goods - RB: Procuring, storing, and issuing goods essential for emergency operations.

<u>Transporting</u>: Providing the capabilities for (1) procuring the use of vehicles and (2) operating and maintaining vehicles, for the transporting of people and goods, as follows:

Relocation of People - RC: Providing for the operation of vehicles to transport those of the public who do not supply their own transportation.

Commuting Essential Workers - RD: Providing for the operation of vehicles to transport essential workers from their temporary lodging in the host areas to their duty stations in the risk areas (and return), including the assuring of the availability of fuel and servicing for the vehicles employed in commuting.

Remedial Movement - RE: Providing and operating vehicles to transport people in an organized remedial movement.

Goods - RF: Transporting of goods for emergency purposes including the resupply of shelters and medical facilities when feasible.

Facilities - RJ: Providing the capabilities for (1) establishing, (2) operating, and (3) maintaining and repairing facilities required for emergency operations, as follows:

Establishing Facilities - RG: Procuring the use of facilities and doing whatever is necessary to render them suitable for their intended emergency use.

Operating Facilities - RH: Performing the activities necessary for use of the facility for its intended emergency purpose, not to include the activities of the emergency operation housed in the facility unless the emergency operation is assigned to the resource service.

Maintaining and Repairing - RI: Accomplishing repairs to existing facilities necessary to assure the continued use of the facility for its emergency purpose, or to prevent deterioration of the facility.

Clearing Debris - RM: Providing the capabilities for removing attack-caused debris or disablements so as to reclaim access to or usability of facilities and routes in the emergency as follows:

Roads - RK: Clearing of debris and other obstructions from roads and other transportation facilities so as to render them passable to the vehicles that use them.

Buildings - RL: Clearing of debris from buildings and from their immediate vicinity so as to (1) obtain access to them from adjacent roadways or (2) render them usable.

Decontaminating - RP: Providing the capabilities for reducing the radiation flux from fallout materials on the surfaces of buildings and terrain through removing or burying the fallout materials, as follows:

Buildings - RN: Removing fallout materials from the surfaces of buildings and their immediate surroundings so as to reduce the radiation flux within the buildings.

Terrain - RO: Removing fallout materials from paved areas and removing or burying fallout materials on unpaved areas so as to reduce the radiation flux in the open and within buildings in the vicinity of the contaminated areas.

Inform D&C - RR: Providing the capabilities for the resource service to inform Direction and Control as to the current situation with respect to attack effects, the condition of the resource service, the availability and condition of facilities and supplies, and so on.

PROTECT INDUSTRY

Providing the necessary capabilities to protect industry so as to increase its potential productivity in the immediate postattack period, as follows:

Hardening: Providing the capabilities for increased resistance to weapon and attack effects, as follows:

Facilities - BA: Increasing the resistance of industrial facilities to damage to themselves and their contents through modification of existing facilities or through modification of the plans and specifications for new facilities.

Equipment - BB: Increasing the resistance of industrial equipment to damage through installation of shields for existing installations or through modification of the design of new equipment.

Inventories - BC: Increasing the resistance of industrial inventories (of both producer and consumer goods) by shielding against weapon effects and by warehousing in lower risk locations.

Emergency Shut Down: Providing the capabilities to reduce damage to industrial property that would result (1) from leaving it unattended or (2) from failing to leave it in its best posture to resist attack effects, as follows:

Facilities - BD: Actions to reduce damage to the facility and its contents because of (1) hazards (principally fire) resulting from leaving it unattended and (2) hazards (principally fire and flooding) resulting from direct and indirect effects of attack.

Processes - BE: Actions to reduce damage to processes from self destruction when the processes are not shut down in an orderly manner.

PROTECT AGRICULTURE

Providing the necessary capabilities to protect agriculture so as to increase its potential productivity in the immediate postattack period, as follows:

Public Preparedness: Providing the capabilities to inform the farm public in relation to protecting themselves, their livestock, and their crops, as follows:

Self Help - GA: Information useful to the farm public for their own activities to mitigate and alleviate the effects of attack in such matters as fire prevention, sanitation, first aid, and the like.

Shelter - GB: Information useful to the farm public for the establishment and occupancy of shelter for residents of farms.

Protect Livestock: Providing the capabilities for protecting agricultural animals against the effects of attack, as follows:

Protection - GC: Shielding agricultural animals against attack effects.

Feeding - GD: Provision for feeding of agricultural animals while it is necessary for them to be shielded and for people to be in shelter because of attack effects.

Protect Crops: Providing the capabilities to protect crops against loss or damage because of attack effects, as follows:

Protect Seed Stock - GE: Protection of seed stock against loss or damage to assure a capability to replant if standing crops are lost.

Decontamination - GF: Removing of the surface contamination of cropland by fallout materials to (1) permit working of the land and (2) reduce uptake of radioactive elements.

DIRECTION AND CONTROL

Providing the necessary capabilities (1) to manage, direct, and control operations in an emergency and (2) to provide support and information, at three levels: Federal, State, and local, as follows:

FEDERAL D&C

Providing the capabilities to direct emergency operations at the national level including operation of the national warning system, as follows:

Support State and Local: Providing the capabilities to support emergency operations at the State and local levels by supplying:

Goods - DA: Controlling available supplies of goods and directing their distribution as required.

Services - DB: Controlling the employment of available emergency service forces and directing their deployment as required.

Information - DC: Supplying available situation information needed by lower echelons for conducting emergency operations and for informing the public.

Informing the Public - DD: Providing the capabilities for the Federal government to inform the public in an emergency as to (1) the situation and (2) preferable ways to alleviate the effects of attack by their own efforts.

Warning the Public - DG: Providing the capabilities to employ the capabilities provided in Warning - AC to warn the public either by direct means or through supplying attack information to local governments, in two areas:

Alerting - DE, and Informing - DF.

STATE D&C

Providing the capabilities to direct emergency operations at the State level, as follows:

Support Local: Providing the capabilities to support emergency operations at the local level by supplying Goods (DH), Services (DI), and Information (DJ).

Inform Federal - DK: Providing the capabilities to inform the Federal government as to the current situation within the State with respect to attack effects, the capability of the State to deal with the emergency, and other matters.

LOCAL D&C

Providing the capabilities for (1) participating in informing the public for their preparedness, (2) warning the public, and (3) informing the public, the State, and the emergency services, as follows:

Public Preparedness: Providing the capabilities to employ the EPI materials and other information so that the public may be informed about Self Help - DL, Warning - DM, Relocation - DN, and Shelter - DO.

Warning the Public - DR: Providing the capabilities to employ the capabilities provided in Warning - AF to warn the public of attack by retransmitting information received from the national warning system in the areas of Alerting - DP and Informing - DQ.

Informing the Public - DS: Providing the capabilities to inform the public in an emergency as to (1) the situation and (2) preferable ways to alleviate the effects of attack by their own efforts.

Informing the System - DZ: Providing the capabilities to inform (1) the State government and the emergency services as to the current situation and (2) the emergency services as to operational requirements and assignments, as follows:

State - DT	Police - DW
Fire - DU	Warden - DX
Medical - DV	Resource - DY

RESEARCH AND DEVELOPMENT - KA

Producing information and developing methods, techniques, prototypes, etc., for use in the design of civil defense countermeasures and systems and in program planning.

FEDERAL PROGRAM MANAGEMENT

Providing and exercising the capability to plan, direct, control, and execute the parts of the program elements that are to be accomplished at the Federal level and to test such parts of the operating system as are in a standby state to ascertain their operational readiness, as follows:

Planning: Providing capabilities and preparing plans as follows:

Program - HA: Obtaining data on the current and projected states of readiness of the operating system and making such adjustments in the overall program plan as are necessary to achieve the goals established in the program design.

Operational - HB: Preparing and modifying plans for emergency operations at the Federal level.

Procurement:

Facilities - HC: Designing, constructing, altering, and maintaining facilities for emergency operations of Federal agencies.

Equipment - HD: Designing, purchasing, transporting, storing, installing, testing, and maintaining non-expendable equipment for use in emergency operations by Federal agencies and for distribution to State and local governments for use in emergency operations.

Materials - HE: Designing, purchasing, transporting, storing, delivering, and maintaining expendable goods, including data, for use in emergency operations by Federal agencies and for distribution to State and local governments for use in emergency operations.

Services - HF: Designing, purchasing, and testing services for emergency operations at the Federal level.

Staffing:

Recruiting - HG: Enrolling people for emergency operating staffs of Federal agencies including payment of salaries or honoraria (when identifiable as such) to such people as inducements to remain enrolled.

Course Instruction - HH: Training individuals for positions in emergency organizations by (1) preparing course materials, (2) training instructors, and (3) instructing individuals for organization at all levels, including operation of the Staff College.

Organization Exercise - HI: Training organizations in emergency operations by conducting (a) exercises of the Federal emergency organization or (b) joint exercises of the Federal and selected combinations of State and/or local emergency organizations.

Supporting State and Local: Providing capabilities and supplying support to State and local governments for program management activities, as follows:

Funds - HJ: Supplying funds to assist State and local governments in program management, including planning, procurement, and staffing activities.

Assistance - HK: Supplying trained individuals to assist State and local governments in program management activities.

Information - HL: Supplying technical and management information needed by State and local governments in program mangement activities.

Administration - HM: Providing capabilities and planning, procurement, and staffing for the conduct of program management activities at the Federal level.

STATE PROGRAM MANAGEMENT

Providing and exercising the capability to plan, direct, control, and exercise the parts of the program elements that are to be accomplished at the State level and to test such parts of the operating system as are in a standby state to ascertain their operational readiness, as follows:

<u>Planning</u>: Providing capabilities and preparing plans as follows:

Program - NA: Obtaining data on the current and projected states of readiness of the operating system and making such adjustments in the overall program plan as are necessary to achieve the goals established in the program design.

Operational - NB: Preparing and modifying plans for emergency operations at the State level.

<u>Procurement</u>:

Facilities - NC: Designing, constructing, altering, and maintaining facilities for emergency operations of State agencies.

Equipment - ND: Designing, purchasing, transporting, storing, installing, testing, and maintaining non-expendable equipment for use in emergency operations by State agencies and for distribution to local governments for use in emergency operations.

Materials - NE: Designing, purchasing, transporting, storing, delivering, and maintaining expendable goods, including data, for use in emergency operations by State agencies and for distribution to local governments for use in emergency operations.

Services - NF: Designing, purchasing, and testing services for emergency operations at the State level.

<u>Staffing</u>:

Recruiting - NG: Enrolling people for emergency operating staffs of State agencies including payment of salaries or honoraria (when identifiable as such) to such people as inducements to remain enrolled.

Course Instruction - NH: Training individuals for positions in emergency organizations by (1) preparing course materials, (2) training instructors, and (3) instructing individuals for organizations at State and local levels.

Organization Exercise - NI: Training organizations in emergency operations by conducting (a) exercises of the State emergency organization or (b) joint exercises of the State and selected combinations of local emergency organizations.

Supporting Local: Providing capabilities and supplying support to local governments for program management activities, as follows:

Funds - NJ: Supplying funds to assist local governments in program management, including planning, procurement, and staffing activities.

Assistance - NK: Supplying trained individuals to assist local governments in program management activities.

Information - NL: Supplying technical and management information needed by local governments in program management activities.

Inform Federal - NM: Supplying information to the Federal government as to (1) the current status of (a) civil defense within the State and (b) the preparedness program; (2) progress in preparedness; and (3) other matters.

Administration - NN: Providing capabilities and planning, procurement, and staffing for the conduct of program management activities at the State level.

LOCAL PROGRAM MANAGEMENT

Providing and exercising the capability to plan, direct, control, and execute the parts of the program elements that are to be accomplished at the local level and to test such parts of the operating system as are in a standby state to ascertain their operational readiness, as follows:

Planning: Providing capabilities and preparing plans as follows:

Program - PA: Obtaining data on the current and projected states of readiness of the operating system and making such adjustments in the overall program plan as are necessary to achieve the goals established in the program design.

Operational - PB: Preparing and modifying plans for emergency operations at the local level.

Procurement:

Facilities - PC: Designing, constructing, altering, and maintaining facilities for emergency operations of local agencies.

Equipment - PD: Designing, purchasing, transporting, storing, installing, testing, and maintaining non-expendable equipment for use in emergency operations.

Materials - PE: Designing, purchasing, transporting, storing, delivering, and maintaining expendable goods, including data, for use in emergency operations.

Services - PF: Designing, purchasing, and testing services for emergency operations.

Staffing:

Recruiting - PG: Enrolling people for emergency operating staffs of local agencies including payment of salaries or honoraria (when identifiable as such) to such people as inducements to remain enrolled.

Course Instruction - PH: Training individuals for positions in emergency organizations by (1) preparing course materials, (2) training instructors, and (3) instructing individuals for local emergency.

Organization Exercise - PI: Training organizations in emergency operations by conducting exercises (a) of the local emergency organization or (b) of elements of the local organization, individually or in selected combinations.

Inform State - PJ: Supplying information to the State government as to (1) the current status of (a) civil defense within the locality and (b) the preparedness program; (2) progress in preparedness; and (3) other matters.

Administration - PK: Providing capabilities and planning, procurement, and staffing for the conduct of program management activities at the local level.

Appendix B

DESCRIPTION OF PROGRAM ANALYSIS MODEL

Appendix B

DESCRIPTION OF PROGRAM ANALYSIS MODEL

CONTENTS

Appendix B

DESCRIPTION OF PROGRAM ANALYSIS MODEL

Introduction

This Appendix describes the Program Analysis Model (PAM) to the extent that it has been developed. The appendix is divided into seven sections corresponding to the POPDEF input parameters PAM is intended to produce. The sequence of the treatment parallels the order in which the parameters enter the POPDEF model. Within each section the presentation starts with the POPDEF parameter and proceeds through the central countermeasures to the countermeasures affording direct and indirect support.

For each part of the model, this appendix gives the flow diagram (system tree) followed by a text that defines the inputs and outputs and describes the relationships in terms of the system algebra. As can be seen in the table of contents, each element of the model is described only once: the first time it appears in a sequence of relationships. When it appears in a later sequence, reference is made to its prior description.

A number of conventions were adopted for use in the system tree and definitive texts. The meaning of each letter code (whether one, two, or three letters) is as it is defined in the text in which it appears. The two-letter code (e.g., PB - Operations Plans) is the basic code and, wherever it is used, its meaning is derived from the definition for it in Appendix A. However, because each element of the organization includes at least people and hardware, it was found necessary to add a third letter to account for relationships within the organization element. As the model now stands, the following third letters are used,

S = staff (organization personnel)

C = communications

E = equipment

F = facilities

M = materials

R = recruiting (on-board personnel)

T = training (of individuals)

Then, for example, DSR is used to refer to on-board D&C public information personnel, DST those who have been individually trained, DSS their capability, and DSC the communications they use.

In use, PAM starts with the state of the system at the start of the preparedness program. For this, the subscript o is added to the three-letter code; e.g., DSR_o refers to on-board D&C public information personnel at program start. The prefix Δ is added to the three letter code to refer to the net accomplishment of the program; e.g., ΔDSR refers to the net change in on-board D&C public information personnel achieved by the program. Throughout the model, the superscript '(prime) is added to indicate a potential capability or effectiveness; e.g., DSS' refers to the potential capability of the D&C public information staff. The prime superscript may be added to one-, two-, or three-letter codes.

Several one-letter codes are used:

- C usually refers to the combined capability of two or more elements of the system.
- E usually refers to the combined effectiveness of two or more elements of the system.
- K represents a modifying factor; e.g., the reliability of radiological instruments or the fraction of the preattack personnel who are effective after the attack.

At a number of places in PAM, allowance has been made for the public to perform some of the functions of the operating system based on the premise that the operating system may not be completely prepared or, even if it is, may not be fully deployed in an emergency. Where this is done, it is identified by a two-letter code with O as the first letter (except in SO) and the second letter either the same as for the warden service function the public is performing or, as in OU - Shelter Monitoring, a function that could be performed by several elements of the CD organization. These codes are listed in Table 11 of the report.

In application, PAM is specific for the set of conditions in which the operations modelled would be conducted. For example, system preparedness in Risk areas might differ from that in Host areas. And system preparedness in relation to the fraction of the population involved might differ within Risk and Host areas depending on (a) whether people had relocated from Risk to Host areas and (b) what fraction of the Risk population had relocated. All such sources of difference need to be considered in order to decide on how many sets of PAM outputs are required in a given evaluation.

The application of all of the PAM system trees to produce two complete sets of POPDEF input parameters is reported in the companion volume to this report:

> Walmer E. Strope, John F. Devaney, and Frederick Miercort,
> Monte Carlo Population Defense Model: Initial Results,
> Center for Planning and Research, Inc. (August 1979)

SECTION B.1

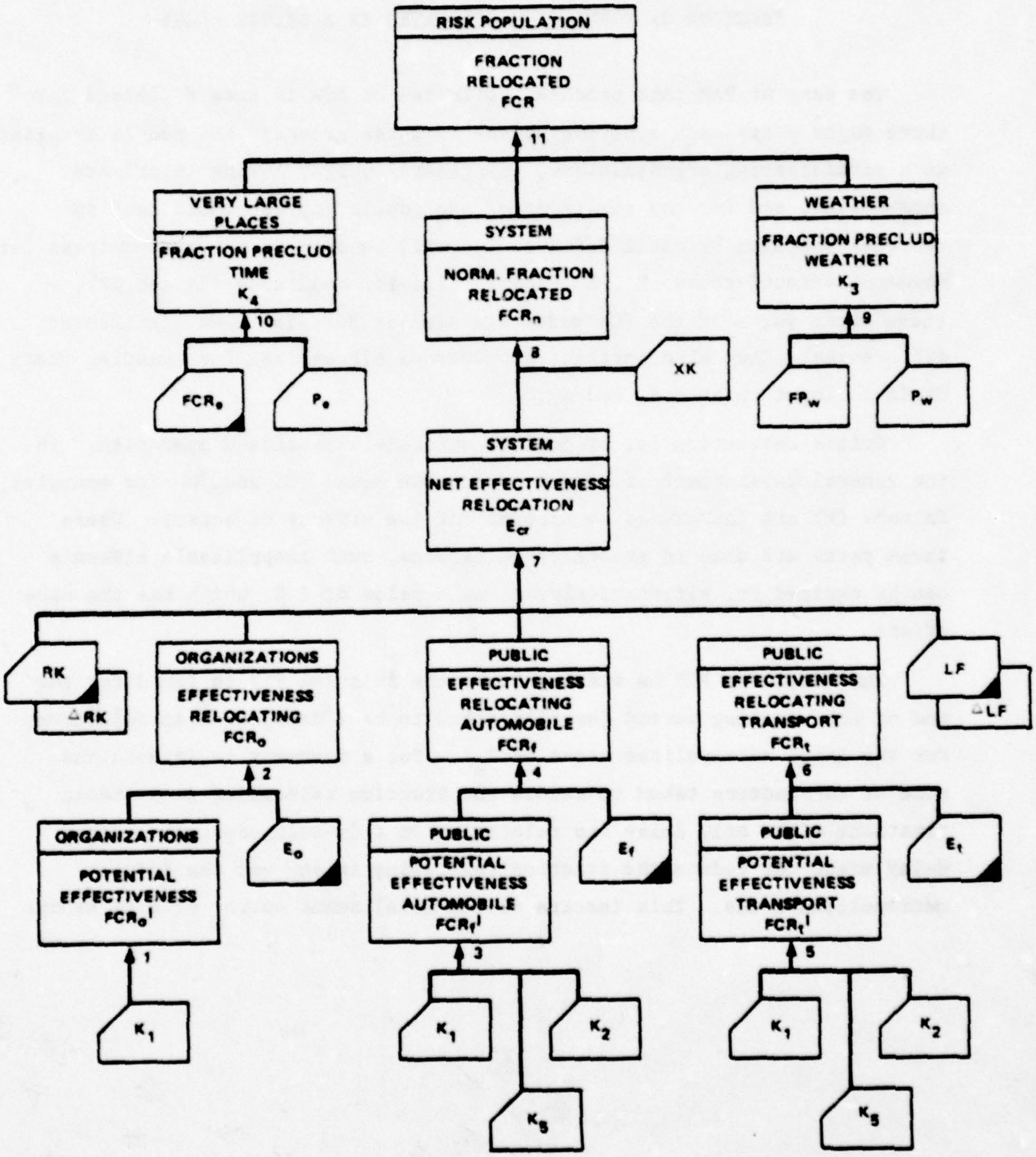
FRACTION OF POPULATION RELOCATED IN A CRISIS (FCR)

The part of PAM that produces estimates of FCR is itself divided into three major parts each applying to one of three groups: (a) people associated with participating organizations, (b) general public moving in private automobiles, and (c) the remainder of the population who would move in vehicles supplied by civil defense. As will be seen in the system trees for movement effectiveness (E_o, E_f, and E_t) and for readiness (CR and OR), these three parts of the FCR model are similar but also have significant differences. They also interact at numerous places, as, for example, where OR is an input to both E_f and E_t.

Crisis relocation is, of course, entirely a preattack operation. In the general development of some parts of the model (DS and RK for example), factors (K) are introduced to account for the effects of attack. Where these parts are used in preattack operations, such inapplicable elements can be excised or, alternatively, given a value of 1.0, which has the same effect.

The model for FCR is static; i.e., the fraction FCR is found for the end of the planning period (usually taken to be 3 days) with an adjustment for the large metropolitan areas (FCR_e). But a movement is dynamic and some of the factors taken to reduce the fraction relocating in a static treatment might only delay the relocation in a dynamic treatment. This delay might not reduce the fraction relocating in any but the largest metropolitan areas. This feature of the model seems worthy of more study.

FRACTION RELOCATED – FCR



FRACTION RELOCATED - FCR

Concept

FCR = fraction of the risk area population who would move from the risk areas to designated host areas within a specified period.

Operation: For consideration of the crisis relocation movement, the people who move are in two classes:

1. Those who move spontaneously on their own resources; i.e., with neither advice nor direction by the government, and

2. The people who move in an organized movement; i.e., a movement planned, directed, and controlled by the CD organization.

For purposes of analysis (and planning), the organized movement is in three parts:

1. Organizations: people associated with organizations, public or private, that intend to move as a unit. For these people, planning of the movement is by the organization in cooperation with CD and, insofar as is possible, the organization supplies the resources necessary for the movement.

2. Public in Autos: people who are not members of organizations who move in accordance with the CD movement plan, at the direction of the government, either
(a) using their own automobiles or
(b) accompanying others in their autos.

3. Public in Supplied Transport: people who are not members of organizations and cannot move in autos and for whom the CD organization arranges for and supplies transportation.

Analysis:

1. Given participating organizations so that,

K_1 = fraction of risk population associated with the participating organizations. Then,

$FCR'_o = K_1$

= fraction of risk population planned to relocate as organizations.

2. Given a fraction of the risk population intended to relocate as organizations and

E_o = the fraction of those who would actually try to relocate. Then,

$FCR_o = E_o \cdot FCR'_o$

= fraction of risk population actually trying to relocate as organizations.

3. Given that some of the risk population can supply their own transportation in their own autos,

K_2 = fraction of risk population having autos, and

K_5 = fraction of risk population without autos who would move with others who do. Then,

$FCR'_f = K_2(1 - K_1) + K_5(1 - K_1)(1 - K_2)$

= fraction of risk population planned to relocate in private autos.

4. Given the fraction of the risk population intended to relocate in private autos, and

E_f = fraction of those who would actually try to relocate. Then,

$FCR_f = E_f \cdot FCR'_f$

= fraction of risk population actually trying to relocate in private autos.

5. Given that some of the risk population would need transportation supplied by the CD organization, then,

$$FCR'_t = (1 - K_1)(1 - K_2)(1 - K_5)$$

= fraction of risk population planned to relocate in supplied transport.

6. Given the fraction of the risk population intended to relocate in supplied transport, and

E_t = fraction of those who would actually try to relocate. Then,

$$FCR_t = E_t \cdot FCR'_t$$

= fraction of risk population actually trying to relocate in supplied transport.

7. Given these three groups trying to relocate along ways subject to blockage and under traffic control that may be less than fully adequate,

ΔRK = maximum change in movement effectiveness between (a) not having any roadway clearing capability and (b) having fully adequate roadway clearing capability,

RK = net capability to clear roadways,

ΔLF = maximum change in movement effectiveness between (a) not having any traffic control capability and (b) having fully adequate traffic control capability, and

LF = net capability to control crisis relocation movement traffic. Then,

$$E_{cr} = (FCR_o + FCR_f + FCR_t)\{1 - \Delta RK(1 - RK)\}\{1 - \Delta LF(1 - LF)\}$$

= fraction of relocating risk population who could move to the host areas if not precluded by adverse weather or the constraint of the specified time limit.

<u>Note</u>: As it now stands, the model says that the net effect of ΔRK and ΔLF is to prevent some people from reaching the host areas with no consideration for the size of the populations in the individual risk areas. It says that traffic jams resulting from blocked roadways or imperfect traffic control either dissuade some people from trying to move or preclude those trying to move from moving. But traffic interruptions reduce the rate at which people would leave the risk area; they do not stop traffic permanently. As the interruptions disappear, traffic would move, those dissuaded could again change their minds, and those trying to move could proceed. Then, traffic interruptions would preclude people from reaching the host areas only in those places where the population is so large that all of those trying to move could not get out within the specified time limit. Thus, the model as it now stands tends to underestimate the effectiveness of the movement and it appears that it should be revised.

8. Given that some of the people who move to the host areas are essential workers who would commute back to the risk areas to work so that,

XK = fraction of the risk population who are key workers in the risk area at the time of the attack. Then,

$FCR_n = E_{cr} - XK$

= fraction of the risk population who would be in the host areas at the time of the attack if not precluded by adverse weather or by the constraint of the specified time limit.

9. Given that adverse weather could preclude some of the risk population from moving to host areas,

FP_w = fraction of risk population subject to adverse weather, and

P_w = probability of occurrence of adverse weather. Then,

$K_3 = FP_w \cdot P_w$

= fraction of risk population who would have otherwise moved to the host areas who are precluded by adverse weather.

10. Given that
(a) all of the risk area population could move to the host areas if sufficient movement time were available and
(b) there is a finite probability that the attack would not occur until some time after the specified planning period.

FCR_e = fraction of risk population who could not move to the host areas within the specified period, and

P_e = probability that the attack would occur at the end of the specified period. Then,

$$K_4 = FCR_e \cdot P_e$$

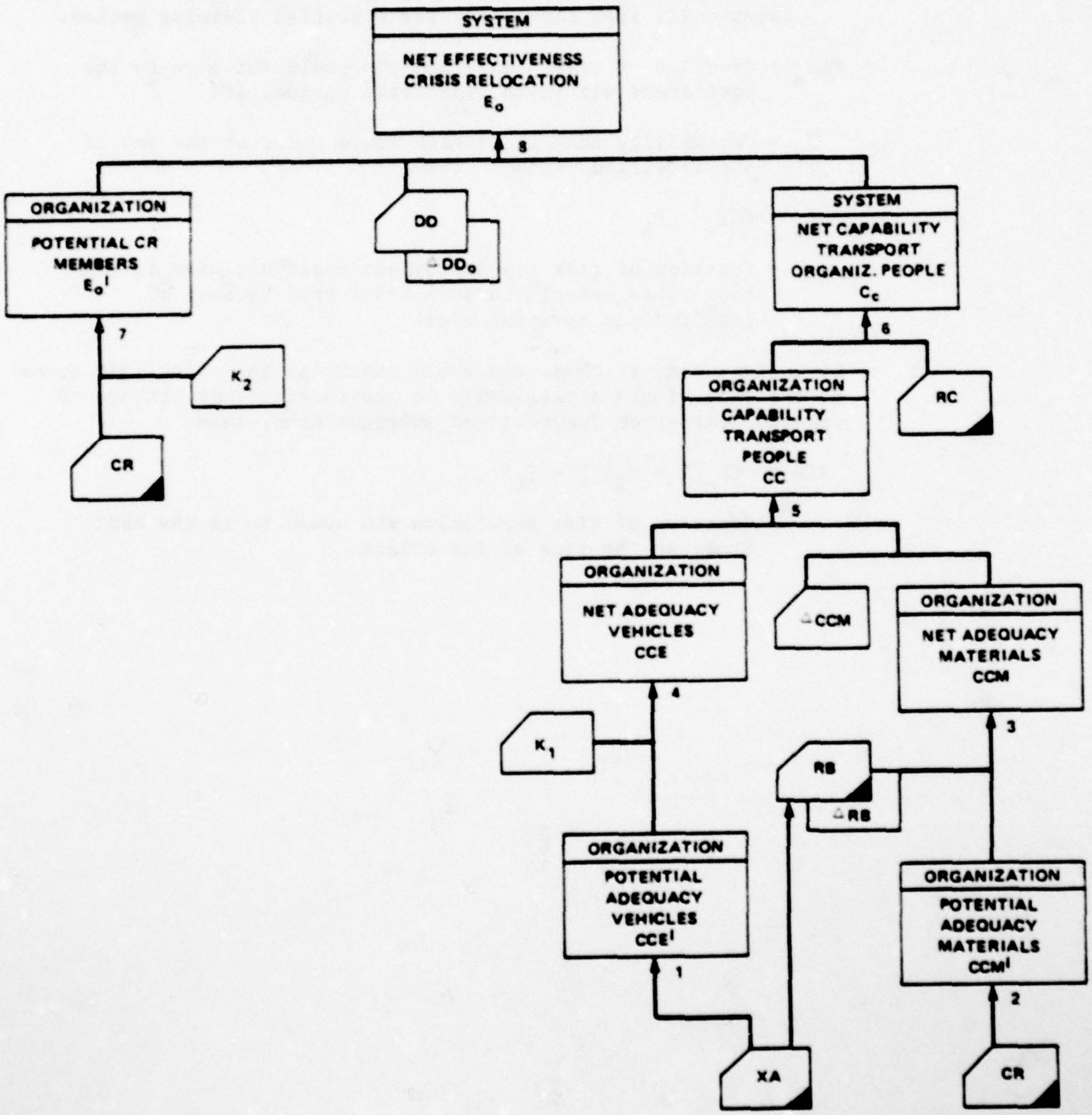
= fraction of risk population who could not move to the host areas before the attack occurred because of insufficient movement time.

11. Given that some of those who would otherwise be in the host areas at the time of the attack would be precluded either because of adverse weather or insufficient movement time, then

$$FCR = FCR_n(1 - K_3)(1 - K_4)$$

= fraction of risk population who would be in the host areas at the time of the attack.

CRISIS RELOCATION – ORGANIZATION MOVEMENT EFFECTIVENESS – E_O



CRISIS RELOCATION - ORGANIZATION MOVEMENT EFFECTIVENESS - E_o

Concept

E_o = net effectiveness of organization relocation movement; i.e., the fraction of those of the risk area population planned to move as organizations who would actually be able to try to move.

Operation: Participating organizations would plan to move their people in cooperation with the CD organization and would supply needed resources to the limit of their ability.

Analysis:

1. Given participating organizations with movement plans that rely in part on members of the organization using their own autos and in part on transport supplied by the organization so that,

   XA = net adequacy of movement plans of participating organizations. Then,

   CCE' = XA

   = fraction of the organization population who would have transport if all planned vehicles would operate when needed.

2. Given that the readiness of the organization population to move includes assurance that their vehicles have sufficient fuel, etc., to reach the host area destination so that,

   CR = fraction of organization population ready and willing to move. Then,

   CCM' = CR

   = fraction of organization population who would have sufficient fuel, etc., provided that civil defense or the participating organization could supply necessary additional amounts.

3. Given
(a) a function of the resource service is to supply materials and
(b) a function of the participating organization is to assure that the resource service can supply fuel, etc., for the organization's population,

ΔRB = maximum change in adequacy of fuel, etc., for the population of participating organizations between
(a) not having any resource service supply capability and
(b) having fully adequate resource service supply capability, and

XA = RB

= net capability of resource service to supply fuel, etc., for population of participating organizations. Then,

$CCM = CCM'\{1 - \Delta RB(1 - RB)\}$

= net adequacy of fuel, etc., for vehicles of population of participating organizations.

4. Given that not all of the vehicles planned for transporting the population of participating organizations would operate when needed so that,

K_1 = fractional reliability of vehicles for organization movement. Then,

$CCE = K_1 \cdot CCE'$

= fraction of organization population having available transport in organization vehicles if sufficient fuel, etc., is available.

5. Given that the availability of fuel, etc., may be insufficient so that,

ΔCCM = maximum change in transport capability of organization vehicles between
(a) not having any fuel, etc., available and
(b) having fully adequate supplies of fuel, etc., available. Then,

$$CC = CCE\{1 - \Delta CCM(1 - CCM)\}$$

= fraction of organization population who could be transported in organization vehicles.

6. Given
(a) that the resource service would supply transport for those of the organization population who could not move in organization vehicles and
(b) that these two transport capabilities are redundant, and

RC = net adequacy of transport supplied by the resource service. Then,

$$C_c = CC + RC - CC \cdot RC$$

= fraction of the organization population who could be transported in a relocation movement.

7. Given that some fraction K_2 of the organization population ready and willing to move would be unable to accompany the organization because of illness or injury, then,

$$E'_o = CR(1 - K_2)$$

= fraction of organization population who are ready and able to move given transportation and a Presidential declaration.

8. Given a fraction of the organization population ready and able to move and a capability to transport them if a crisis relocation is ordered,

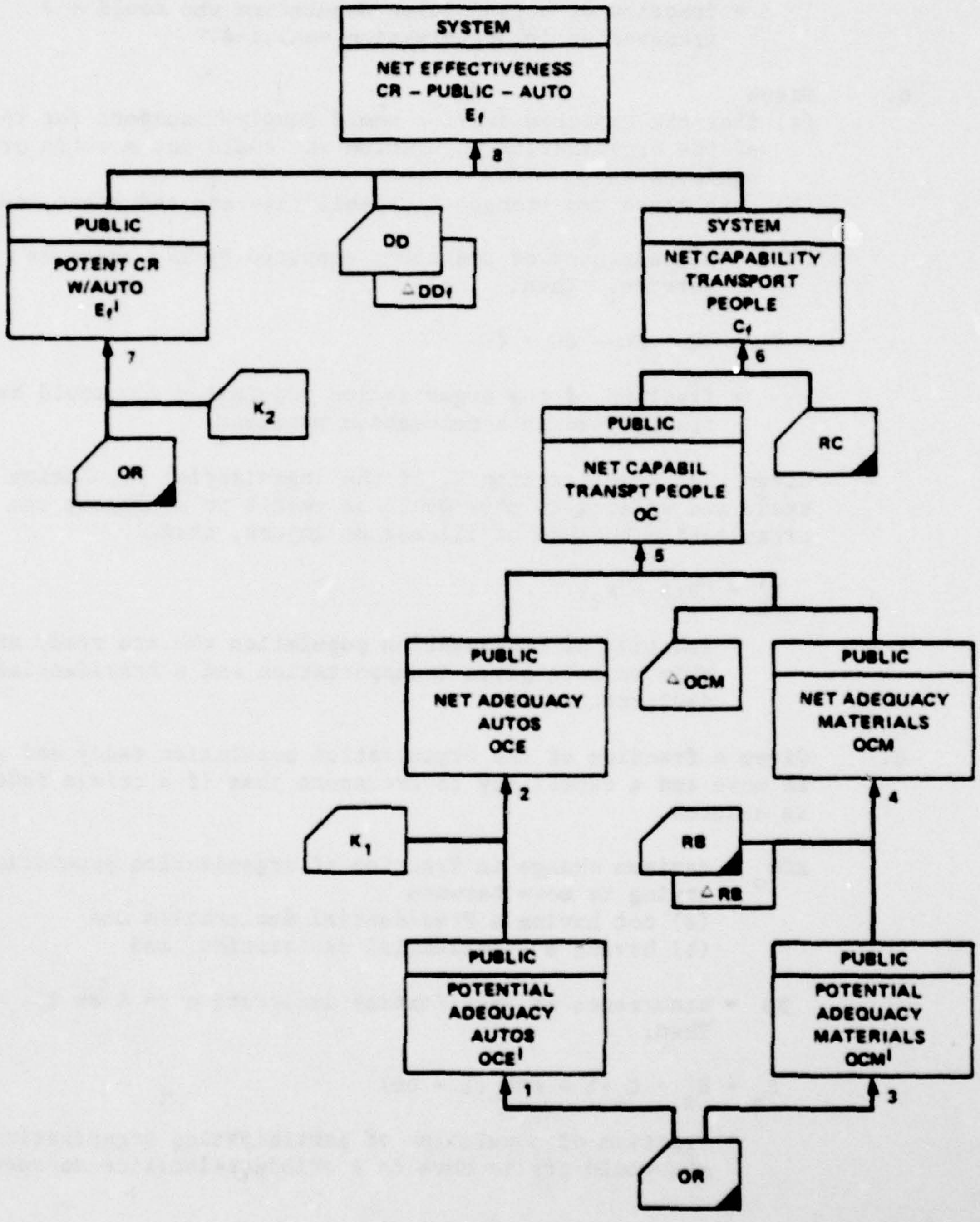
ΔDD_o = maximum change in fraction of organization population trying to move between
(a) not having a Presidential declaration and
(b) having a Presidential declaration, and

DD = occurrence of Presidential declaration (= 0 or 1). Then,

$$E_o = E'_o \cdot C_c\{1 - \Delta DD_o(1 - DD)\}$$

= fraction of population of participating organizations who would try to move in a crisis relocation movement.

CRISIS RELOCATION – EFFECTIVENESS W/AUTO – E_f



CRISIS RELOCATION
MOVEMENT EFFECTIVENESS WITH AUTO - E_f

Concept

E_f = net effectiveness of relocation movement of public with autos; i.e., the fraction of those of the risk area population, not associated with participating organizations, planned to move in private autos who would actually be able to try to move.

Operations: Members of the risk area public who have their own automobiles and are ready and willing will move to the host areas in them if the vehicles will operate. Civil defense will supply transport for those planned to use their own autos but whose autos will not be operable when needed.

Analysis:

1. Given a fraction of the risk public planned to relocate in private auto and ready and willing to go so that,

   OR = fraction of the risk public ready and able to move. Then,

   $OCE' = OR$

   = fraction of the risk public with autos if they will operate when needed.

2. Given that not all of the autos planned for use in relocation will operate when needed so that,

   K_1 = fraction of autos planned for public transport in relocation movement that will operate when needed given fuel, etc. Then,

   $OCE = K_1 \cdot OCE'$

   = fraction of the risk public who are planned to relocate in private autos who will have operable autos.

3. Given that the fraction of the risk public ready and able to move in autos should have assured that they have sufficient fuel, etc. Then,

$OCM' = OR$

= fraction of risk public planned to relocate in private autos who would have sufficient fuel, etc., if resupplied.

4. Given the resource service supply function so that,

ΔRB = maximum change in adequacy of fuel, etc. for private autos between
(a) not having any resource service supply capability, and
(b) having fully adequate resource service supply capability, and

RB = net capability of resource service to supply fuel, etc., for private autos. Then,

$$OCM = OCM'\{1 - \Delta RB(1 - RB)\}$$

= fraction of risk public planned to move in private autos who would have sufficient fuel, etc.

5. Given that transportation of people in private autos depends on having fuel, etc. so that,

ΔOCM = maximum change in capability to transport people in autos between
(a) not having any fuel, etc., and
(b) having fully adequate supplies of fuel, etc. then,

$$OC = OCE\{1 - \Delta OCM(1 - OCM)\}$$

= fraction of risk public planned to relocate in private autos who could actually be transported in them.

6. Given
(a) that the transport capability of private autos - OC may be less than 1.0,
(b) that the resource service should supply transport to relieve the shortfall, and
(c) that transport by private auto and supplied transport are redundant, and

RC = fraction of risk public for whom resource service can supply transport. Then,

$C_f = OC + RC - OC \cdot RC$

= fraction of risk public planned to relocate in private autos who can actually be transported by all means.

7. Given that some of those of the risk public who are planned to move in autos will be unable to move in them because of illness or injury so that,

K_2 = fraction of those of the risk public planned to move in autos who are unable to go. Then

$E'_f = OR(1 - K_2)$

= fraction of those of the risk public planned to move in autos who are ready and able to go given transportation and a Presidential declaration.

8. Given a fraction of the risk public ready and able to move and a capability to transport them,

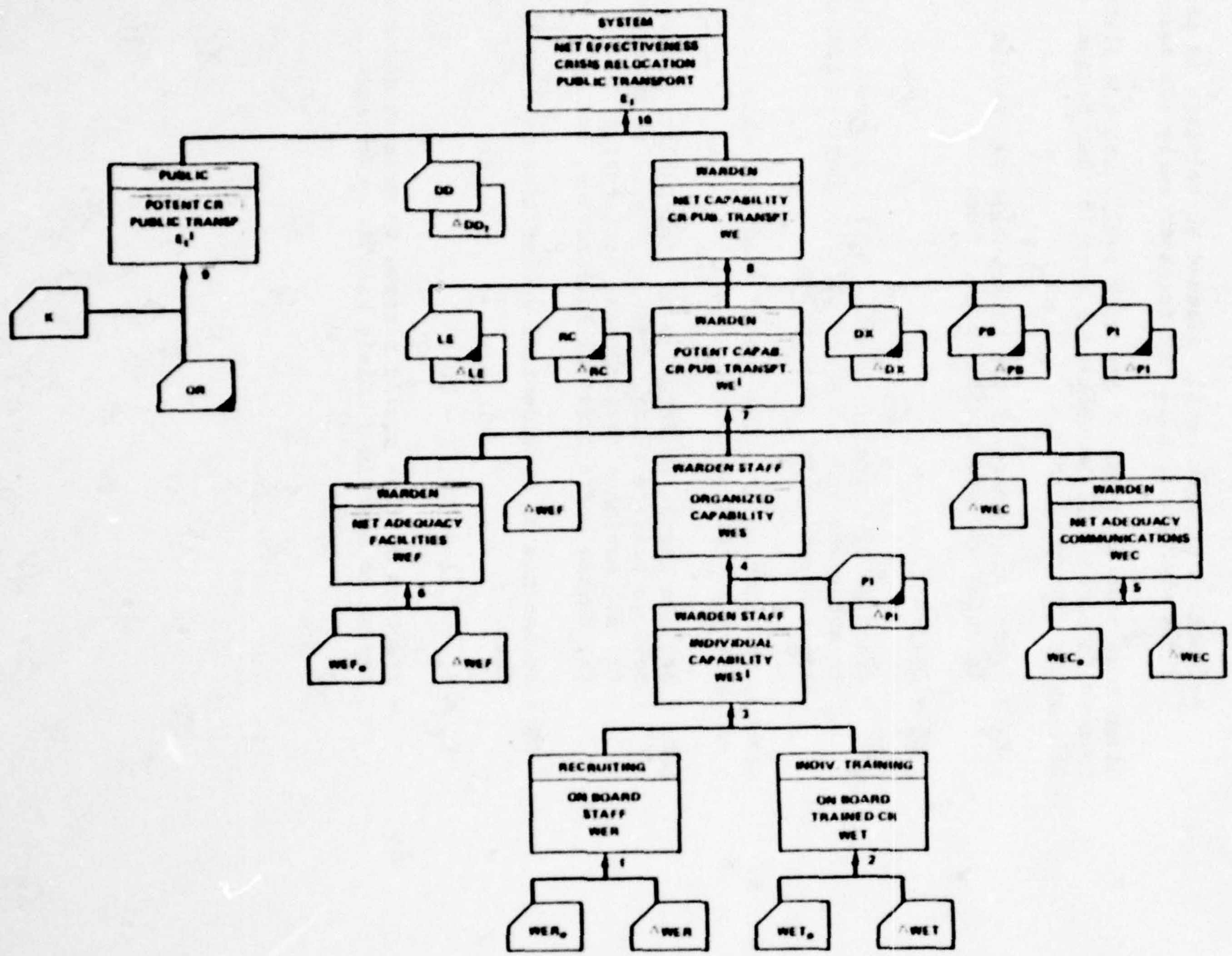
ΔDD_f = maximum change in fraction of risk public, planned to move in private autos, actually trying to move between (a) not having a Presidential declaration and (b) having a Presidential declaration, and

DD = occurrence of Presidential declaration (= 0 or 1). Then,

$E_f = E'_f \cdot C_f\{1 - \Delta DD_f(1 - DD)\}$

= fraction of risk public planned to move in autos actually trying to move in a crisis relocation movement.

CRISIS RELOCATION – MOVEMENT EFFECTIVENESS – SUPPLIED TRANSPORT – E_t



CRISIS RELOCATION
MOVEMENT EFFECTIVENESS - SUPPLIED TRANSPORT - E_t

Concept

E_t = net effectiveness of relocation movement of public without autos; i.e., the fraction of those of the risk area population, not associated with participating organizations, planned to move in transport supplied by the CD organization who would actually be able to try to move.

Operation: Members of the risk area population who do not have autos and cannot move with those who do will be transported in vehicles supplied and operated by the resource service. Management of the movement -- including assembly of the people at loading points and loading of the vehicles -- will be by the warden service with information support by D&C and maintenance of order support by the police service.

Analysis:

1. Given a warden service with a crisis relocation movement staff,

WER_o = fraction of risk population with adequate movement staff at program start, and

ΔWER = net additional fraction for whom movement staff is recruited in program. Then,

$$WER = WER_o + \Delta WER$$

= fraction of risk population with adequate movement staff at program completion.

2. Given an on-board warden service movement staff that should be trained for crisis relocation movement management,

WET_o = fraction of risk population with adequate trained movement staff at program start, and

ΔWET = net additional fraction for whom movement staff is trained in program. Then,

$$WET = WET_o + \Delta WET$$

= fraction of risk population with adequate trained movement staff at program completion.

3. Given that some of the movement staff may be lost because of staff turnover either before or after being trained, then,

$WES' = \text{Min } WER : WET$

= fraction of the risk population with adequate movement staff who have had individual training in crisis relocation movement management.

4. Given that organization exercise in emergency operations can increase staff capability so that,

ΔPI = maximum change in movement staff capability between (a) not having any exercise of the movement staff and (b) having fully adequate exercise of the movement staff, and

PI = net adequacy of exercises for training of the movement staff. Then,

$WES = WES'\{1 - \Delta PI(1 - PI)\}$

= fraction of the risk population having fully competent movement staff at program completion.

5. Given that the warden service could have service communications for the movement staff so that,

WEC_o = fraction of the risk population with adequate communications for the movement staff at program start, and

ΔWEC = net additional fraction for whom movement staff communications are procured in program. Then,

$WEC = WEC_o + \Delta WEC$

= fraction of risk population with adequate movement staff communications at program completion.

6. Given that the warden service could have facilities for managing the movement of people in supplied transport,

WEF_o = fraction of risk population with adequate movement facilities at program start, and

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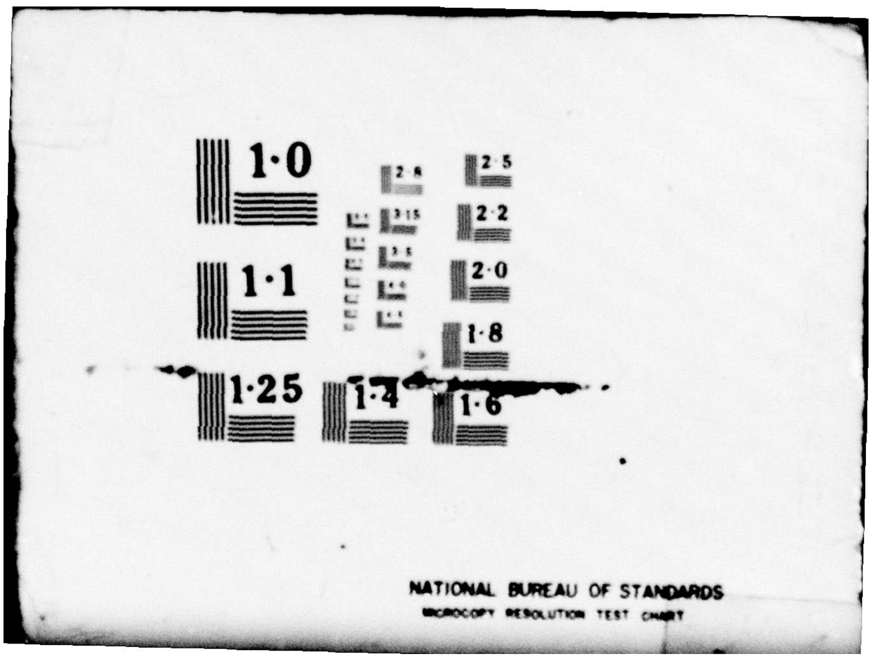
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MICROCOPY RESOLUTION TEST CHART

ΔWEF = net additional fraction for whom facilities are procured in program. Then,

$$WEF = WEF_o + \Delta WEF$$

= fraction of risk population with adequate movement facilities at program completion.

7. Given that
(a) communications and facilities can enhance the management capability of the movement staff and
(b) it would be limited by the lesser of them,

ΔWEC = maximum change in movement staff capability between
(a) not having any communications and
(b) having fully adequate communications, and

ΔWEF = maximum change in movement staff capability between
(a) not having any facilities and
(b) having fully adequate facilities. Then,

$$WE' = WES \cdot \mathrm{Min}\{1 - \Delta WEC(1 - WEC)\} : \{1 - \Delta WEF(1 - WEF)\}$$

= fraction of risk population with adequate capability to move people in supplied transport given the necessary support.

8. Given that the CD organization should supply support to the warden service in transporting people,

ΔLE = maximum change in transport capability between
(a) not having any police service maintenance of order at loading points and
(b) having fully adequate police service maintenance of order,

LE = net capability of police service to maintain order at loading points,

ΔRC = maximum change in transport capability between
(a) not having any supply of vehicles by the resource service and
(b) having fully adequate supply of vehicles,

RC = net capability of resource service to supply and operate transport vehicles,

ΔDX = maximum change in transport capability between
(a) not having any D&C capability to inform the warden service and
(b) having fully adequate D&C system information capability

DX = net capability of D&C to supply system information to the warden service,

ΔPB = maximum change in transport capability between
(a) not having the activity treated in operations plans and
(b) having fully adequate treatment in operations plans,

PB = net adequacy of treatment of movement by supplied transport in operations plans,

ΔPI = maximum change in transport capability between
(a) not having any exercise of the CD organizations in crisis relocation movement and
(b) having fully adequate organization exercise, and

PI = net adequacy of exercise of the CD organization in crisis relocation movement in supplied transport. Then,

$$WE = WE'\{1 - \Delta LE(1 - LE)\}\{1 - \Delta RC(1 - RC)\}\{1 - \Delta DX(1 - DX)\}\{1 - \Delta PB(1 - PB\ \}\{1 - \Delta PI(1 - PI)\}$$

= fraction of the risk population who can be transported in supplied transport in a crisis relocation movement.

9. Given that not all of those of the risk public ready and willing to move could move because of illness or injury so that,

K = fraction of those ready and willing to move who would be unable to go. Then,

$$E_t' = OR(1 - K)$$

= fraction of the risk population planned to move in supplied transport who would be ready and able to move given transportation and a Presidential declaration.

10. Given a fraction of the risk population ready and able to move and a capability to transport then,

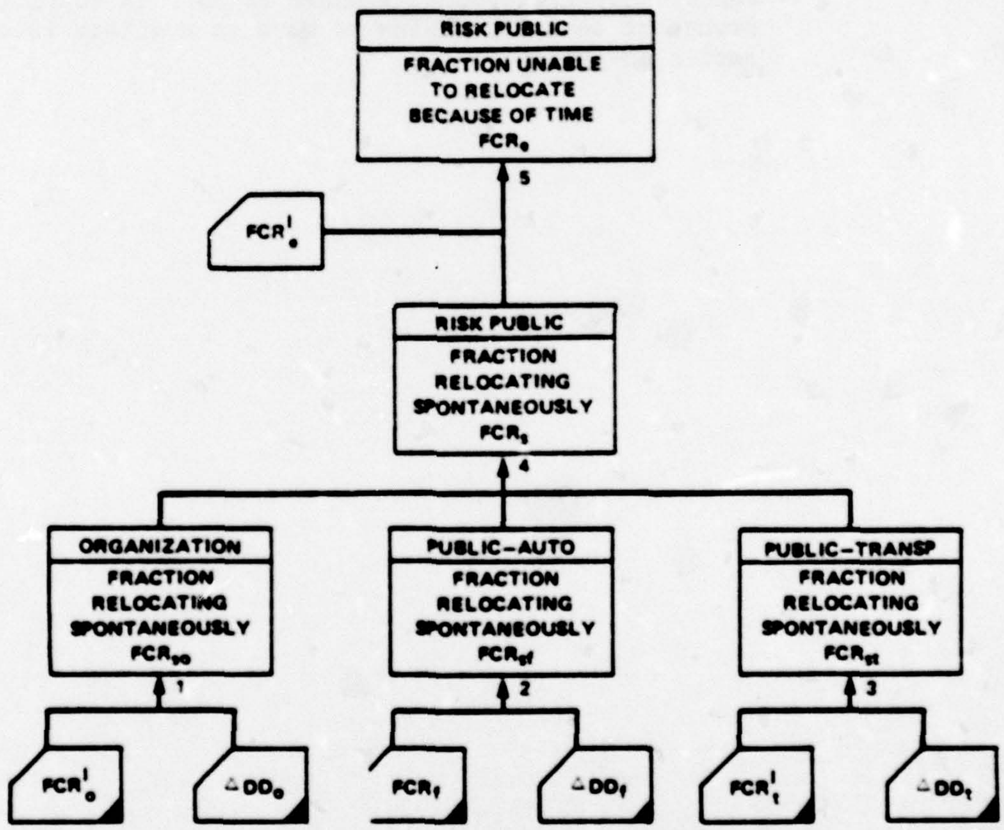
ΔDD_t = maximum change in fraction of risk public, planned to move in supplied transport actually trying to move between
(a) not having a Presidential declaration and
(b) having a Presidential declaration, and

DD = occurrence of Presidential declaration (= 0 or 1). Then,

$$E_t = E_t' \cdot WE\{1 - \Delta DD_t)(1 - DD)\}$$

= fraction of risk public planned to move in supplied transport actually trying to move in a crisis relocation movement.

CRISIS RELOCATION
FRACTION PRECLUDED BY INSUFFICIENT TIME – FCR_e



CRISIS RELOCATION
FRACTION OF RISK POPULATION UNABLE TO RELOCATE BECAUSE OF INSUFFICIENT TIME - FCR_e

Concept

FCR_e = fraction of risk area population unable to complete a crisis relocation movement within the specified time limit.

Operation: In planning for crisis relocation a period for movement from risk to host areas in a directed relocation is specified as a planning goal. Because of the numbers of people to be moved in some of the largest metropolitan areas, it may not be possible to move all of the people within the specified planning period. The numbers to be moved in the directed movement would be reduced by the numbers of those who would relocate spontaneously; i.e., those who would relocate on their own initiative without a Presidential declaration.

Analysis:

1. Given that some of the fraction of the risk area population planned to move with participating organizations could relocate spontaneously,

FCR'_o = fraction of risk population planned to relocate with participating organizations, and

ΔDD_o = fraction of organization population who would decide to relocate because of a Presidential declaration. Then,

$$FCR_{so} = FCR'_o(1 - \Delta DD_o)$$

= fraction of risk population planned to relocate with participating organizations who would be expected to relocate spontaneously.

2. Given that some of the fraction of the risk area population planned to move in private autos could relocate spontaneously,

FCR'_f = fraction of risk population planned to relocate in private autos, and

ΔDD_f = fraction of population with autos who would decide to relocate because of a Presidential declaration. Then,

$FCR_{sf} = FCR'_f(1 - \Delta DD_f)$

= fraction of risk population planned to relocate in private autos who would be expected to relocate spontaneously.

3. Given that some of the fraction of the risk area population planned to move in supplied transport could relocate spontaneously,

FCR'_t = fraction of risk population planned to relocate in supplied transport, and

ΔDD_t = fraction of population with supplied transport who would decide to relocate because of a Presidential declaration. Then,

$FCR_{st} = FCR'_t(1 - \Delta DD_t)$

= fraction of risk population planned to relocate in supplied transport who would be expected to relocate spontaneously.

4. Given these three groups independently relocating spontaneously,

$FCR_s = FCR_{so} + FCR_{sf} + FCR_{st}$

= fraction of risk population who would be expected to relocate spontaneously.

5. Given that some fraction of the risk population would be unable to relocate within the movement period specified for planning so that,

FCR'_e = fraction of risk population who would be unable to relocate within the specified planning period if no spontaneous relocation occurred. Then,

$FCR_e = FCR'_e(1 - FCR_s)$

= fraction of the risk population who would be unable to relocate within the movement period specified for planning.

CRISIS RELOCATION - FRACTION OF ORGANIZATION POPULATION READY AND WILLING TO MOVE - CR

Concept

CR = fraction of the population associated with participating organizations who are ready and willing to move in a crisis relocation movement.

Operation: People need to be informed as to what they must do to participate in a relocation movement and to be persuaded to do it. The specifics of the information come from the organization's movement plan and are disseminated by the management and also by members of the organization. General situation information is disseminated by D&C.

Analysis: (System tree overleaf)

1. Given participating organizations with movement plans so that,

   XA = net adequacy of treatment of specific information in organization movement plan. Then,

   CM' = XA

   = fraction of organization population to whom management is trying to give specific information.

2. Given that the management may not be fully effective in informing its members so that,

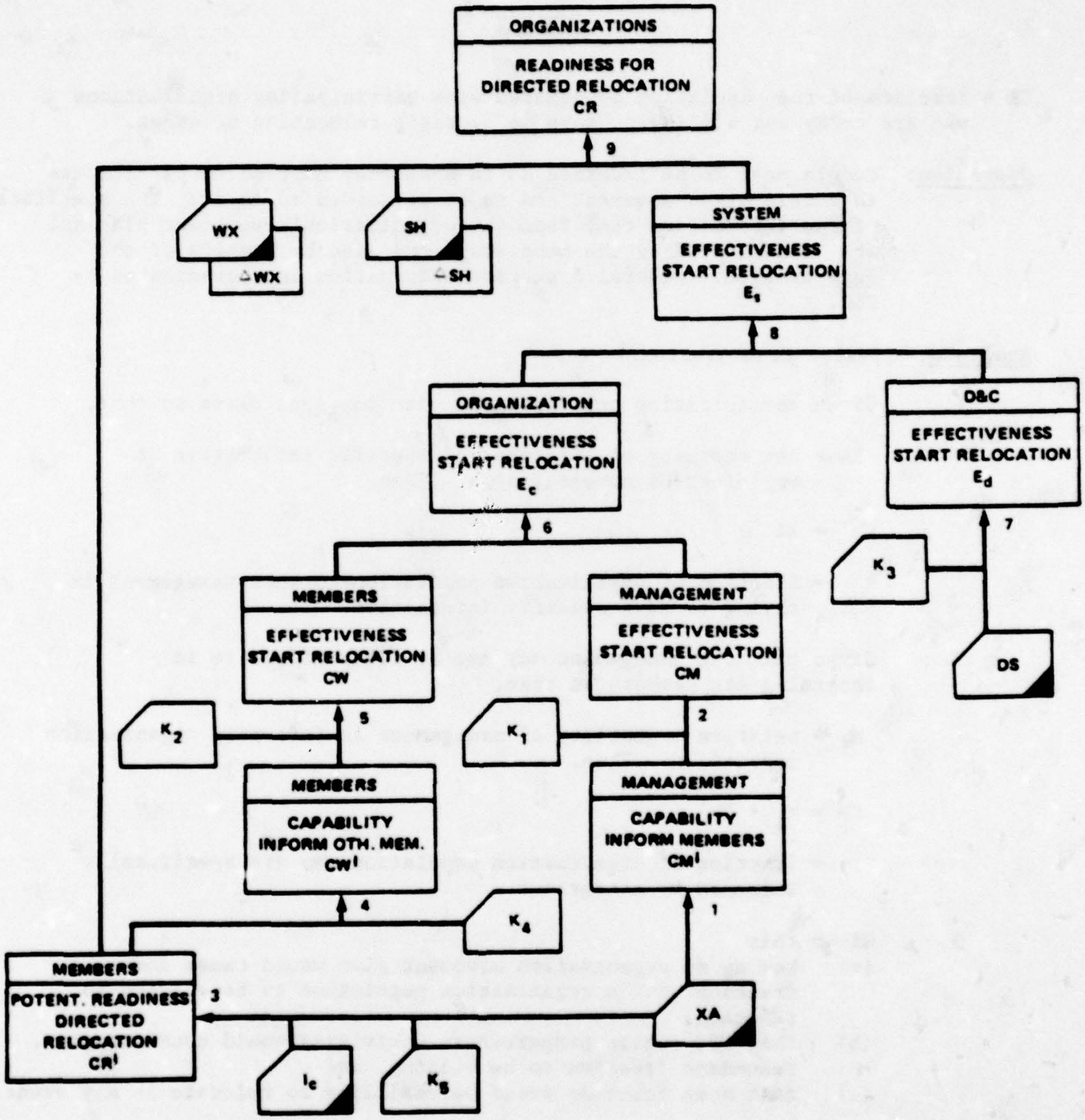
   K_1 = relative capability of management in informing organization population. Then,

   $CM = K_1 \cdot CM'$

   = fraction of organization population who are specifically informed by management.

3. Given that
   (a) having an organization movement plan would cause some fraction of the organization population to be willing to relocate,
   (b) that EPI public preparedness activities would cause another, redundant fraction to be willing, and
   (c) that some fraction would be unwilling to relocate in any event,

CRISIS RELOCATION – FRACTION OF ORGANIZATION POPULATION READY AND WILLING TO MOVE – CR



I_c = fraction willing to relocate because of EPI public preparedness,

XA = fraction willing to relocate because of movement plans, and

K_5 = fraction unwilling to relocate under any circumstances, then,

$$CR' = (XA + I_c - XA \cdot I_c)(1 - K_5)$$

4. Given that some of the members of the organization who are willing to relocate would attempt to inform others so that,

K_4 = fraction of willing members who would attempt to inform others. Then,

$$CW' = K_4 \cdot CR'$$

= fraction of organization population trying to inform others.

5. Given that members of the organization may not be fully effective in informing others so that,

K_2 = relative capability of organization members in informing others. Then,

$$CW = CW'(1 + K_2)$$

= fraction of organization population who can be informed by other members of the organization.

6. Given that any member of the organization can be informed either by the management or by another member but need be informed only once, then,

$$E_c = CM + CW - CM \cdot CW$$

= fraction of organization population given specific information.

7. Given a D&C capability to disseminate general information in which it may not be fully effective,

DS = fraction of population with adequate public information capability, and

K_3 = relative capability of D&C to inform organization population. Then,

$E_d = K_3 \cdot DS$

= fraction of organization population who can be informed by D&C.

8. Given two redundant ways in which the organization population can be informed, then,

$E_s = E_c + E_d - E_c E_d$

= fraction of organization population who can be informed about the crisis relocation movement.

9. Given that having knowledge of the preparations being made in the host area for reception and care and for sheltering will affect the number of organization people willing to move and that the media will make information about the state of these preparations known,

ΔSH = maximum change in fraction of organization population willing to relocate between
(a) having a perception that host area shelter preparations are not adequate and
(b) having a perception that host area shelter preparations are fully adequate,

SH = perceived adequacy of host area shelter preparations,

ΔWX = maximum change in fraction of organization population willing to relocate between
(a) having a perception that host area preparations for reception and care are not adequate and
(b) having a perception that reception and care preparations are fully adequate, and

WX = perceived adequacy of host area preparations for reception and care. Then,

$CR = CR' \cdot E_s\{1 - \Delta SH(1 - SH)\}\{1 - \Delta WX(1 - WX)\}$

= fraction of organization population ready and willing to move in a crisis relocation.

CRISIS RELOCATION - FRACTION OF THE PUBLIC READY AND WILLING TO MOVE - OR

Concept

OR = fraction of the risk area public not associated with participating organizations who are ready and willing to move in a crisis relocation movement.

Operation: People need to be informed as to what they must do to participate in a relocation movement and to be persuaded to do it. The specifics of the information come from the movement plan and are disseminated by D&C with the assistance of public safety services (police) and the warden service. In addition, some people would inform and persuade. All of these means are redundant. In addition, D&C disseminates general information about crisis relocation.

Analysis: (System tree overleaf)

1. Given a D&C with a public information capability that may be less than fully effective,

   DS = net capability of D&C to disseminate specific relocation information for the public, and

   K_1 = relative capability of D&C to inform the public then,

   $E_d = K_1 \cdot DS$

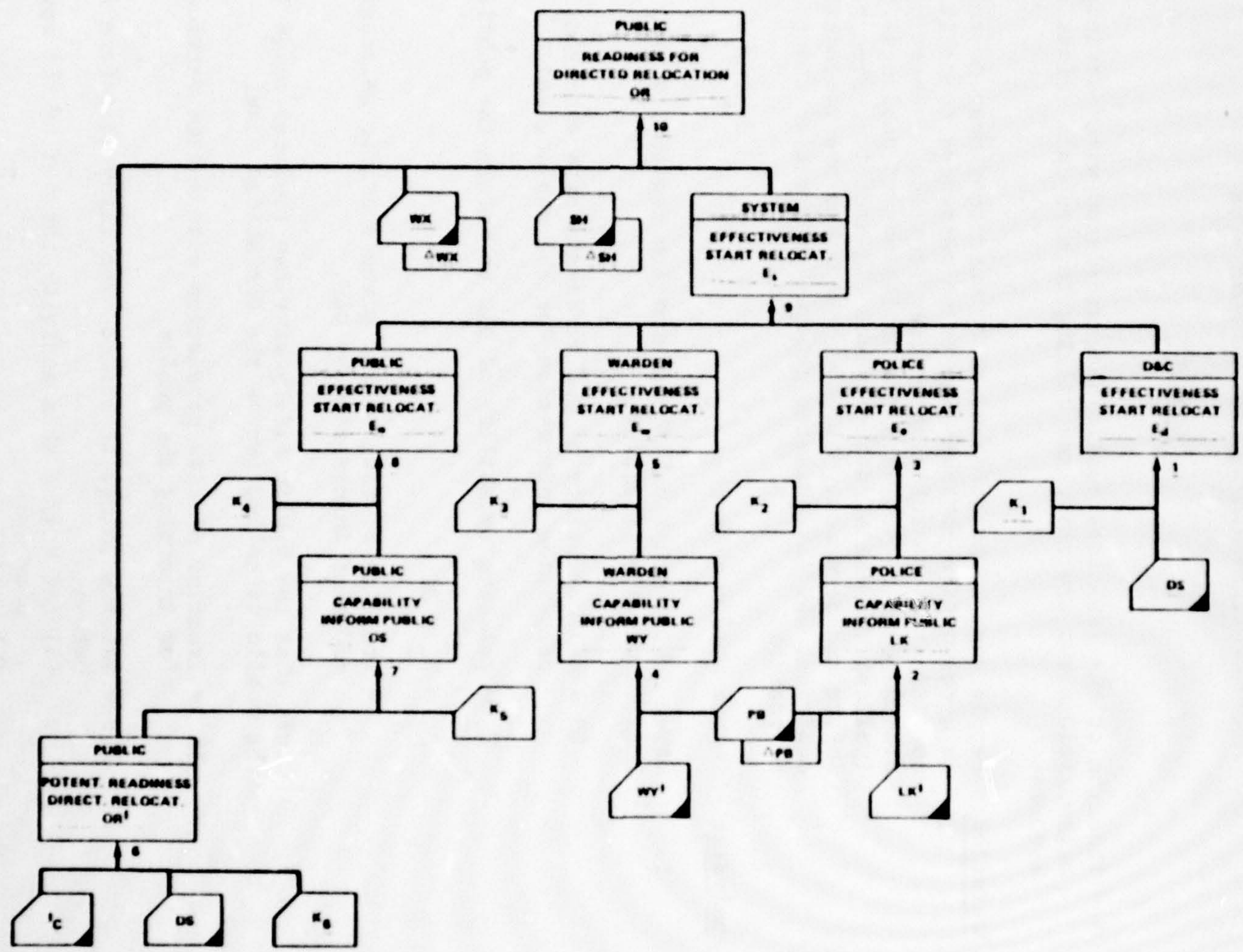
   = fraction of risk public given specific relocation movement information by D&C.

2. Given that the public safety services (police) could inform the public if called for in the operations plan,

   LK' = fraction of risk population with police service adequate for informing the public,

   ΔPB = maximum change in police capability to inform the public between
   (a) not having this activity treated in the operations plan and
   (b) having this activity adequately treated in the operations plan, and

CRISIS RELOCATION – FRACTION OF RISK PUBLIC READY AND WILLING TO MOVE – OR



PB = net adequacy of treatment of police informing activity in operations plan. Then,

$LK = LK'\{1-\Delta PB(1-PB)\}$

= fraction of the risk public with police trying to inform them.

3. Given that the police may not be fully effective in informing the public so that,

K_2 = relative capability of police in informing the public. Then,

$E_\ell = K_2 \cdot LK$

= fraction of risk public who can be informed by police

4. Given that the warden service could inform the public if called for in the operations plan,

WY' = fraction of risk public with warden service adequate for informing the public,

ΔPB = maximum change in warden capability to inform the public between
(a) not having this activity treated in the operations plan and
(b) having this activity adequately treated in the operations plan, and

PB = net adequacy of treatment of warden informing activity in operations plan. Then,

$WY = WY'\{1-\Delta PB(1-PB)\}$

= fraction of the risk public with warden trying to inform them.

5. Given that the warden service may not be fully effective in informing the public so that,

K_3 = relative capability of warden service in informing the public. Then,

$E_w = K_3 \cdot WY$

= fraction of risk public who can be informed by warden service.

6. Given EPI activities to prepare the public for crisis relocation, a separate D&C capability to disseminate general relocation information, and some fraction of the public unwilling to relocate,

I_c = fraction of risk public who would be ready and willing to relocate if informed because of EPI public preparedness,

DS = fraction of risk public who would be ready and willing to relocate if informed because of D&C general public information.

K_6 = fraction unwilling to relocate under any circumstances, then,

$OR' = (I_c + DS - I_c \cdot DS)(1 - K_6)$

= fraction of risk public who would be ready and willing to relocate if informed.

7. Given that some fraction of the potentially ready and willing risk public would try to inform others. Then,

K_5 = fraction of the potentially ready and willing risk public who would try to inform others. Then,

$OS = K_5 \cdot OR'$

= fraction of risk public trying to inform others.

8. Given that members of the public may not be fully effective in informing others so that,

K_4 = relative capability of the public to inform others. Then,

$E_o = OS + K_4 \cdot OS$

= fraction of risk public informed by other members of the public.

9. Given that any member of the public could be informed by any of the four means but need not be informed more than once,

$$E_s = E_d + E_\ell + E_w + E_o$$
$$- E_dE_\ell - E_dE_w - E_dE_o - E_\ell E_w - E_\ell E_o - E_wE_o$$
$$+ E_dE_\ell E_w + E_dE_\ell E_o + E_dE_wE_o + E_\ell E_wE_o$$
$$- E_dE_\ell E_wE_o$$

= fraction of the risk public informed about the crisis relocation movement.

10. Given that having knowledge of the preparations being made in the host area for reception and care and for sheltering will affect the number of people willing to move and that the media will make information about the state of these preparations known.

ΔSH = maximum change in fraction of risk public willing to relocate between
(a) having a perception that host area shelter preparations are not adequate and
(b) having a perception that host area shelter preparations are fully adequate,

SH = perceived adequacy of host area shelter preparations,

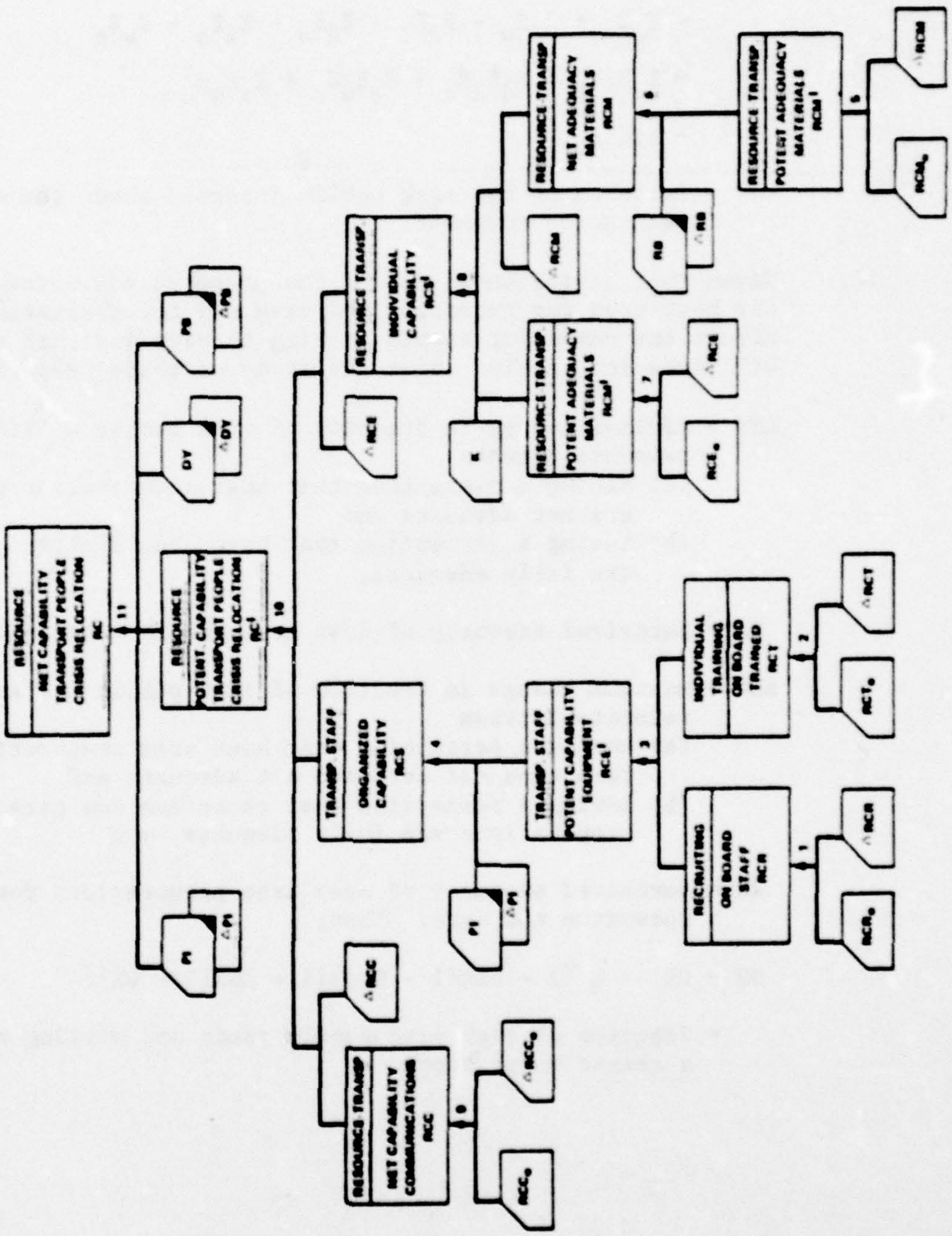
ΔWX = maximum change in fraction of risk public willing to relocate between
(a) having a perception that host area preparations for reception and care are not adequate and
(b) having a perception that reception and care preparations are fully adequate, and

WX = perceived adequacy of host area preparations for reception and care. Then,

$$OR = OR' \cdot E_s \{1 - \Delta SH(1 - SH)\}\{1 - \Delta WX(1 - WX)\}$$

= fraction of risk area public ready and willing to move in a crisis relocation.

CRISIS RELOCATION – TRANSPORT CAPABILITY – RC



CRISIS RELOCATION
SUPPLIED TRANSPORT CAPABILITY - RC

Concept

RC = net capability of the resource service to supply and operate vehicles to transport people in a crisis relocation movement.

Operation: The resource service has the function of supplying transportation in a crisis relocation movement for those who cannot move in their own autos or with others who can. In this case, "supply" would likely mean to arrange with transit companies, school bus fleets, and the like to supply vehicles, drivers, dispatchers, maintenance personnel, etc.

Analysis:

1. Given a resource service with a transportation staff including CD organization personnel and those who would operate the vehicles by arrangement,

   RCR_o = fraction of risk population with adequate transport staff at program start, and

   ΔRCR = net additional fraction for whom transport staff is recruited in program. Then,

   $RCR = RCR_o + \Delta RCR$

   = fraction of risk population with adequate transport staff at program completion.

2. Given an on-board transport staff who would be trained in crisis relocation movement,

   RCT_o = fraction of risk population with adequate trained transport staff at program start, and

   ΔRCT = net additional fraction for whom transport staff is trained in program. Then,

   $RCT = RCT_o + \Delta RCT$

   = fraction of risk population with adequate trained transport staff at program completion.

3. Given that some of the transport staff may be lost because of staff turnover either before or after training, then,

RCS' = Min RCR : RCT

= fraction of risk population with adequate transport staff individually trained for crisis relocation movement.

4. Given that service exercise for training can enhance staff capability so that,

ΔPI = maximum change in transport staff capability between (a) not having any service exercise for training and (b) having fully adequate service exercises, and

PI = net adequacy of transport staff exercises. Then,

RCS = RCS'{1 - ΔPI(1 - PI)}

= fraction of risk population with adequate, competent transport staff at program completion.

5. Given that transport vehicles require fuel, etc. available when needed,

RCM_o = fraction of risk population with adequate availability of fuel, etc. at program start, and

ΔRCM = net additional fraction for whom availability of fuel, etc. is arranged in program. Then,

RCM' = RCM_o + ΔRCM

= fraction of risk population with adequate availability of fuel etc. at program completion provided resupply is available.

6. Given a resource service function of assuring the availability of resupply of fuel, etc., so that,

ΔRB = maximum change in adequacy of supplies of fuel, etc. between
(a) not having any resource service resupply capability and
(b) having fully adequate resupply capability, and

RB = net capability of resource service to assure resupply of fuel, etc. Then,

$$RCM = RCM'\{1 - \Delta RB(1 - RB)\}$$

= fraction of risk population with adequate supplies of fuel, etc. for supplied transport.

7. Given that vehicles are required for transporting people,

RCE_o = fraction of risk population with adequate vehicle availability at program start, and

ΔRCE = net additional fraction for whom availability of vehicles is arranged in program. Then,

$$RCE' = RCE_o + \Delta RCE$$

= fraction of risk population with adequate availability of vehicles at program completion provided vehicles will operate when needed and adequate supplies of fuel, etc. are available.

8. Given that some vehicles may not operate when needed and that supplies of fuel, etc. may be insufficient so that,

K = fraction of available vehicles that will operate when needed, and

ΔRCM = maximum change in vehicle capability between (a) not having any supplies of fuel, etc. and (b) having fully adequate supplies. Then,

$$RCE = K \cdot RCE'\{1 - \Delta RCM(1 - RCM)\}$$

= fraction of risk population with adequate availability of operable vehicles when needed.

9. Given that resource service may have communications for the transport staff,

RCC_o = fraction of risk population with adequate transport staff communications at program start, and

ΔRCC_o = net additional fraction for whom communications are procured in program. Then,

$$RCC = RCC_o + \Delta RCC$$

= fraction of risk population with adequate transport staff communications at program completion.

10. Given that
(a) equipment and communications enhance the capability of the transport staff and
(b) it would be limited by the lesser of them,

ΔRCE = maximum change in transport capability between
(a) not having any vehicles and
(b) having fully adequate vehicle availability, and

ΔRCC = maximum change in transport capability between
(a) not having any transport staff communications and
(b) having fully adequate communications. Then,

$$RC' = RCS \cdot \mathrm{Min}\{1 - \Delta RCE(1 - RCE)\} : \{1 - \Delta RCC(1 - RCC)\}$$

= fraction of risk population with adequate capability for supplied transport at program completion provided resource service is adequately supported.

11. Given that the resource service should be supported,

ΔPI = maximum change in transport capability between
(a) not having any CD organization exercise in supplying transport for crisis relocation and
(b) having fully adequate exercises,

PI = net adequacy of CD organization exercises,

ΔDY = maximum change in transport capability between
(a) not having any D&C capability to inform the resource service and
(b) having fully adequate D&C information capability,

DY = net capability of D&C to supply system information to the resource service,

ΔPB = maximum change in transport capability between
(a) not having supply of transport treated in operations plans and
(b) having fully adequate treatment, and

PB = net adequacy of treatment of transport supply in operations plans. Then,

$$RC = RC'\{1 - \Delta PI(1 - PI)\}\{1 - \Delta DY(1 - DY)\}\{1 - \Delta PB(1 - PB)\}$$

= fraction of risk population for whom the resource service can supply adequate transport capability for a crisis relocation movement.

RESOURCE - CLEARING ROADS - RK

Concept

RK - net capability of the resource service to clear debris from roads and other ways to permit their use for emergency transport.

Operation: The resource service would employ heavy equipment, trucks, etc., to remove disabled vehicles and attack-caused debris from roadways to permit their use.

Analysis: (System tree overleaf)

1. Given a resource service with a road debris clearance staff,

   RKR_o = fraction of population having adequate road debris clearance staff at program start, and

   ΔRKR = net additional fraction for whom road debris clearance staff are recruited in program. Then,

   $RKR = RKR_o + \Delta RKR$

   = fraction of population having adequate road debris clearance staff at program completion.

2. Given an on-board road debris clearance staff who should be trained in emergency debris clearance,

   RKT_o = fraction of population having adequate trained road debris clearance staff at program start, and

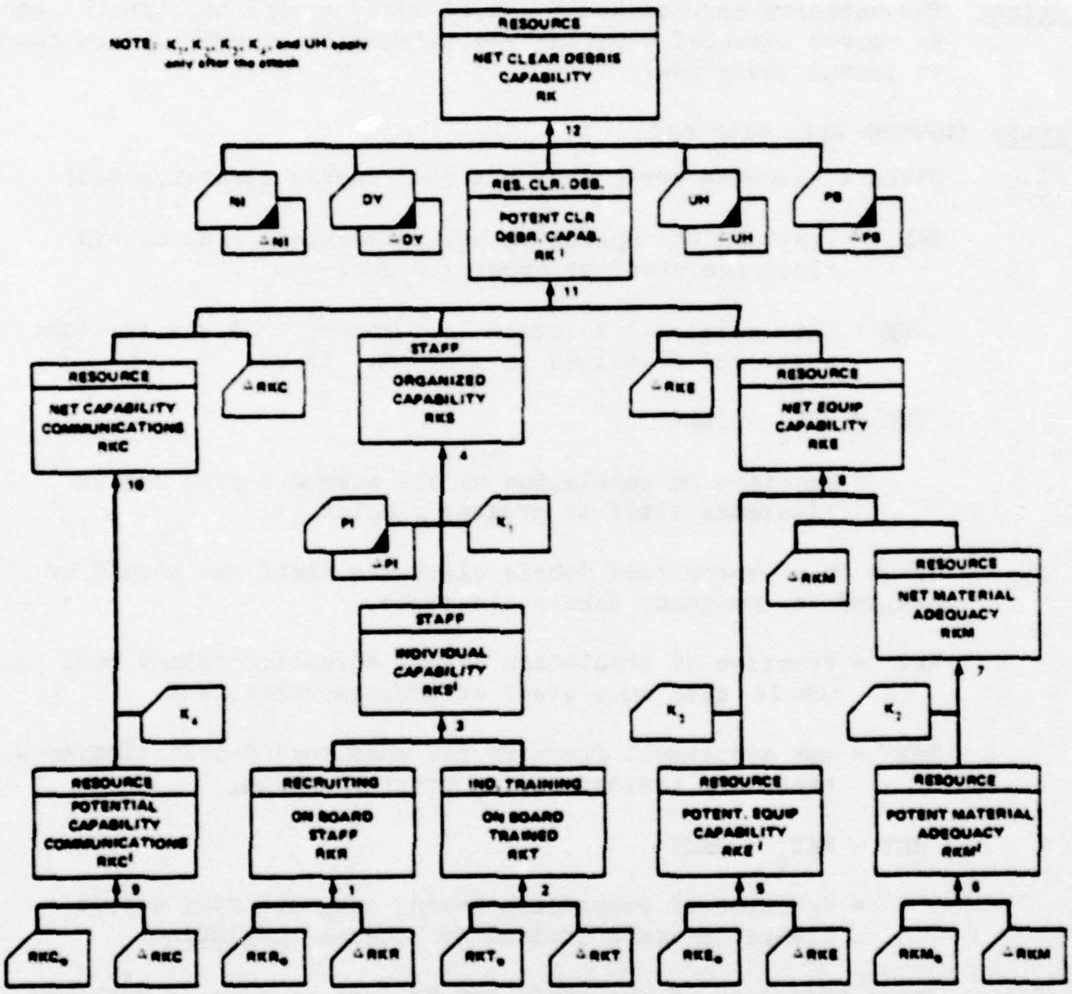
   ΔRKT = net additional fraction for whom road debris clearance staff are trained during program. Then,

   $RKT = RKT_o + \Delta RKT$

   = fraction of population having adequate road debris clearance staff trained by program completion.

3. Given that some of the staff may be lost because of turnover either before or after training, then,

RESOURCE – CLEARING ROADS – RK



$RKS' = \text{Min } RKR : RKT$

= fraction of population with adequate road debris clearance staff who are individually trained at program completion.

4. Given
(a) that service exercises can enhance the capability of the staff and
(b) that the effects of attack would incapacitate some of the staff,

ΔPI = maximum change in capability of road debris clearance staff between
(a) not having any service exercise and
(b) having fully adequate service exercises,

PI = net adequacy of exercises of road debris clearance staff, and

K_1 = fraction of debris clearance staff effective after attack effects. Then,

$$RKS = K_1 \cdot RKS'\{1 - \Delta PI(1 - PI)\}$$

= fraction of population with effective road debris clearance staff after attack effects. *

5. Given that road clearance requires equipment,

RKE_o = fraction of population with adequate road clearance equipment at program start, and

ΔRKE = net additional fraction for whom equipment is procured in program. Then,

$$RKE' = RKE_o + \Delta RKE$$

= fraction of population with adequate road clearance equipment at program completion provided necessary materials are available.

6. Given that road clearance requires materials for use in and with the equipment,

---

* K_1 = 1.0 for preattack operations.

RKM_o = fraction of population having adequate materials for road debris clearance at program start, and

ΔRKM = net additional fraction for whom adequate materials are procured during program. Then,

$RKM' = RKM_o + \Delta RKM$

= fraction of population with adequate road clearance materials at program completion.

7. Given that some materials could be lost because of attack effects so that,

K_2 = fraction of road clearance materials available and usable after attack. Then,

$RKM = K_2 \cdot RKM'$

= fraction of population with adequate road clearance materials after attack.*

8. Given
(a) that some equipment could be lost because of attack effects and
(b) that the capability of the surviving equipment could depend on materials availability,

K_3 = fraction of road clearance equipment available and operable after attack, and

ΔRKM = maximum change in equipment capability between
(a) not having any necessary materials and
(b) having a fully adequate supply of materials. Then,

$RKE = K_3 \cdot RKE'\{1 - \Delta RKM(1 - RKM)\}$

= fraction of population with adequate road clearance equipment capability after attack.*

9. Given that the resource service may have communications for the road clearance staff,

---

* K_2 and K_3 = 1.0 for preattack operations.

RKC_o = fraction of population having adequate road debris clearance communications at program start, and

ΔRKC = net additional fraction for whom communications are procured during program. Then,

$RKC' = RKC_o + \Delta RKC$

= fraction of population having adequate road clearance communications at program completion.

10. Given that some communications could be lost because of attack effects so that,

K_4 = fraction of road clearance communications functioning after attack. Then,

$RKC = K_4 \cdot RKC'$

= fraction of population with functioning road clearance communications after attack.*

11. Given that
(a) equipment and communications can enhance staff capability and
(b) it would be limited by the lesser of them,

ΔRKE = maximum change in potential road debris clearance capability between
(a) not having any equipment operating capability and
(b) having fully adequate equipment operating capability, and

ΔRKC = maximum change in potential road debris clearance capability between
(a) not having any communications and
(b) having fully adequate communications. Then,

$RK' = RKS \cdot \text{Min}\{1 - \Delta RKE(1 - RKE)\} : \{1 - \Delta RKC(1 - RKC)\}$

= fraction of population with adequate road clearance capability if resource service is adequately supported.

12. Given that the resource service should be supported,

ΔNI = maximum change in road clearance capability between
(a) not having any joint State/local CD organization exercise and
(b) having fully adequate exercises,

---

* K_4 = 1.0 for preattack operations.

NI = net adequacy of joint State/local CD organization exercises,

ΔDY = maximum change in road clearance capability between
(a) not having any D&C information support and
(b) having fully adequate D&C information support,

DY = net capability of D&C to supply system information to resource service,

ΔUH = maximum change in road clearance capability between
(a) not having self-help RADEF and
(b) having fully adequate self-help RADEF

UH = net self-help RADEF capability of road clearance staff,

ΔPB = maximum change in road clearance capability between
(a) not having any treatment of road clearance in operations plans and
(b) having fully adequate treatment, and

PB = net adequacy of treatment of road clearance in operations plans. Then,

$$RK = RK'\{1 - \Delta NI(1 - NI)\}\{1 - \Delta DY(1 - DY)\}\{1 - \Delta UH(1 - UH)\}\{1 - \Delta PB(1 - PB)\}$$

= fraction of population with adequate resource service capability to clear roads after attack.*

* ΔUH = 0 for preattack operations.

CRISIS RELOCATION
TRAFFIC CONTROL CAPABILITY - LF

Concept

LF = net capability of police service to control traffic in a crisis relocation movement.

Operation: The police service would control traffic in a crisis relocation movement by directing the placing of barricades across roadways not in the planned road net, by directing traffic at intersections, and by locating, reporting, and taking steps to clear bottlenecks slowing or stopping traffic flow.

Analysis: (System tree overleaf)

1 Given a police service with relocation traffic control staff,

LFR_o = fraction of population having adequate relocation traffic control staff at start of program, and

ΔLFR = net additional fraction for whom traffic control staff is recruited during program. Then,

$LFR = LFR_o + \Delta LFR$

= fraction of population having adequate relocation traffic control staff at program completion.

2. Given an on-board traffic control staff that should be trained for crisis relocation,

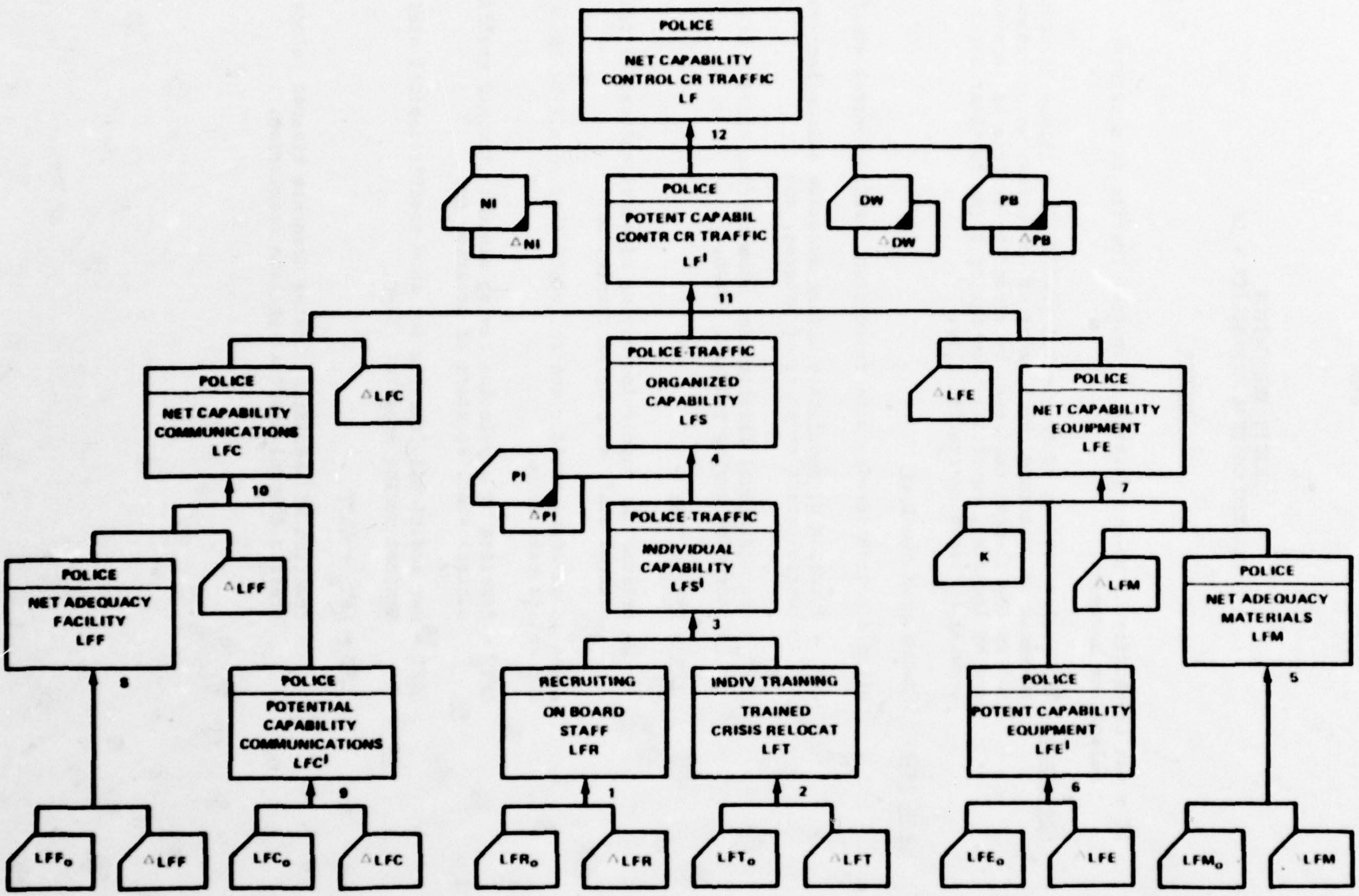
LFT_o = fraction of population having adequate trained traffic control staff at start of program, and

ΔLFT = net additional fraction for whom traffic control staff are trained during program. Then,

$LFT = LFT_o + \Delta LFT$

= fraction of population having adequate trained relocation traffic control staff at program completion.

CRISIS RELOCATION — TRAFFIC CONTROL CAPABILITY — LF



3. Given that some of the staff may be lost because of turnover either before or after being trained, then,

$LFS' = \text{Min } LFR : LFT$

= fraction of population having adequate traffic control staff individually trained for crisis relocation at program completion.

4. Given that service exercises can enhance staff capability so that,

ΔPI = maximum change in traffic control staff capability between (a) not having any service exercise for training and (b) having fully adequate exercises, and

PI = net adequacy of service exercises for training. Then,

$LFS = LFS'\{1 - \Delta PI(1 - PI)\}$

= fraction of population having fully capable relocation traffic control staff at program completion.

5. Given that police vehicles can require fuel, etc.,

LFM_o = fraction of population having adequate materials for traffic control equipment at start of program, and

ΔLFM = net additional fraction for whom materials are procured during program. Then,

$LFM = LFM_o + \Delta LFM$

= fraction of population having adequate traffic control materials at program completion.

6. Given that traffic control police can use vehicles,

LFE_o = fraction of population having adequate traffic control equipment at start of program, and

ΔLFE = net additional fraction for whom equipment is procured during program. Then,

$LFE' = LFE_o + \Delta LFE$

= fraction of population for whom adequate equipment is available at program completion provided all vehicles operate when needed and sufficient fuel, etc., is available.

7. Given
(a) that not all vehicles will operate when needed and
(b) supplies of fuel, etc. may be insufficient,

K = fraction of available vehicles that will operate when needed, and

ΔLFM = maximum change in vehicle capability between
(a) not having any fuel, etc. and
(b) having fully adequate supplies of fuel, etc.. Then,

$LFE = K \cdot LFE'\{1 - \Delta LFM(1 - LFM)\}$

= fraction of population with adequate relocation traffic control vehicle capability.

8. Given that police services traditionally operate out of stations in which communications centers are located,

LFF_o = fraction of population having adequate police facilities at start of program, and

ΔLFF = net additional fraction for whom facilities will be procured during program. Then,

$LFF = LFF_o + \Delta LFF$

= fraction of population with adequate police facilities at program completion.

9. Given that traffic control forces should have communications,

LFC_o = fraction of population having adequate traffic control communications at start of program, and

ΔLFC = net additional fraction for whom communications are procured during program. Then,

$LFC' = LFC_o + \Delta LFC$

= fraction of population having adequate traffic control communications at program completion.

10. Given that traffic control communications capability may depend on having police facilities so that,

ΔLFF = maximum change in traffic control communications capability between
(a) not having any police facilities and
(b) having fully adequate police facilities. Then,

$LFC = LFC'\{1 - \Delta LFF(1 - LFF)\}$

= fraction of population with adequate traffic control communications at program completion.

11. Given that
(a) the capability of the traffic control police can be enhanced by equipment and communications and
(b) it would be limited by the lesser of them,

ΔLFC = maximum change in capability of traffic control staff between
(a) not having any communications capability and
(b) having fully adequate communications capability, and

ΔLFE = maximum change in capability of traffic control staff between
(a) not having any equipment capability and
(b) having fully adequate equipment capability. Then,

$LF' = LFS \cdot MIN\{1 - \Delta LFC(1 - LFC)\} : \{1 - \Delta LFE(1 - LFE)\}$

= potential relocation traffic control capability of police service if adequately supported by D&C service information, operations plans, and organization exercises.

12. Given that the police service should be supported by the organization,

ΔNI = maximum change in traffic control capability between
(a) not having any joint State/local CD organization exercise and
(b) having fully adequate organization exercises,

NI = net adequacy of joint State/local organization exercise in crisis relocation movement,

ΔDW = maximum change in police traffic control capability between (a) not having any D&C system information support and (b) having fully adequate D&C information support,

DW = net capability of D&C to supply system information to the police service,

ΔPB = maximum change in police traffic control capability between
(a) not having any treatment of relocation traffic control in operations plans and
(b) having fully adequate treatment of relocation traffic control in operations plans.

PB = net adequacy of treatment of crisis relocation traffic control in operations plans. Then,

$$LF = LF'\{1 - \Delta NI(1 - NI)\}\{1 - \Delta DW(1 - DW)\}\{1 - \Delta PB(1 - PB)\}$$

= fraction of population having adequate police service capability for controlling traffic in a crisis relocation movement.

RESOURCE - SUPPLY GOODS - RB

Concept

RB = net capability of resource service to assure the availability of goods for emergency operations.

Operation: It is likely that except for extraordinary items such as resupply of water to shelters, for example, goods would be supplied in an emergency by those who normally supply them. However, arrangements with these suppliers would need to be made and emergency operating procedures established. And in the emergency, the suppliers would require information and assistance. The resource service function would include making the arrangements and supplying information and assistance.

Analysis: (System tree overleaf)

1. Given a resource service with a supply staff,

RBR_o = fraction of population having adequate supply staff at program start, and

ΔRBR = net additional fraction for whom supply staff is recruited in program. Then,

$RBR = RBR_o + \Delta RBR$

= fraction of population with adequate supply staff at program completion.

2. Given an on-board supply staff that should be trained in emergency supply of goods,

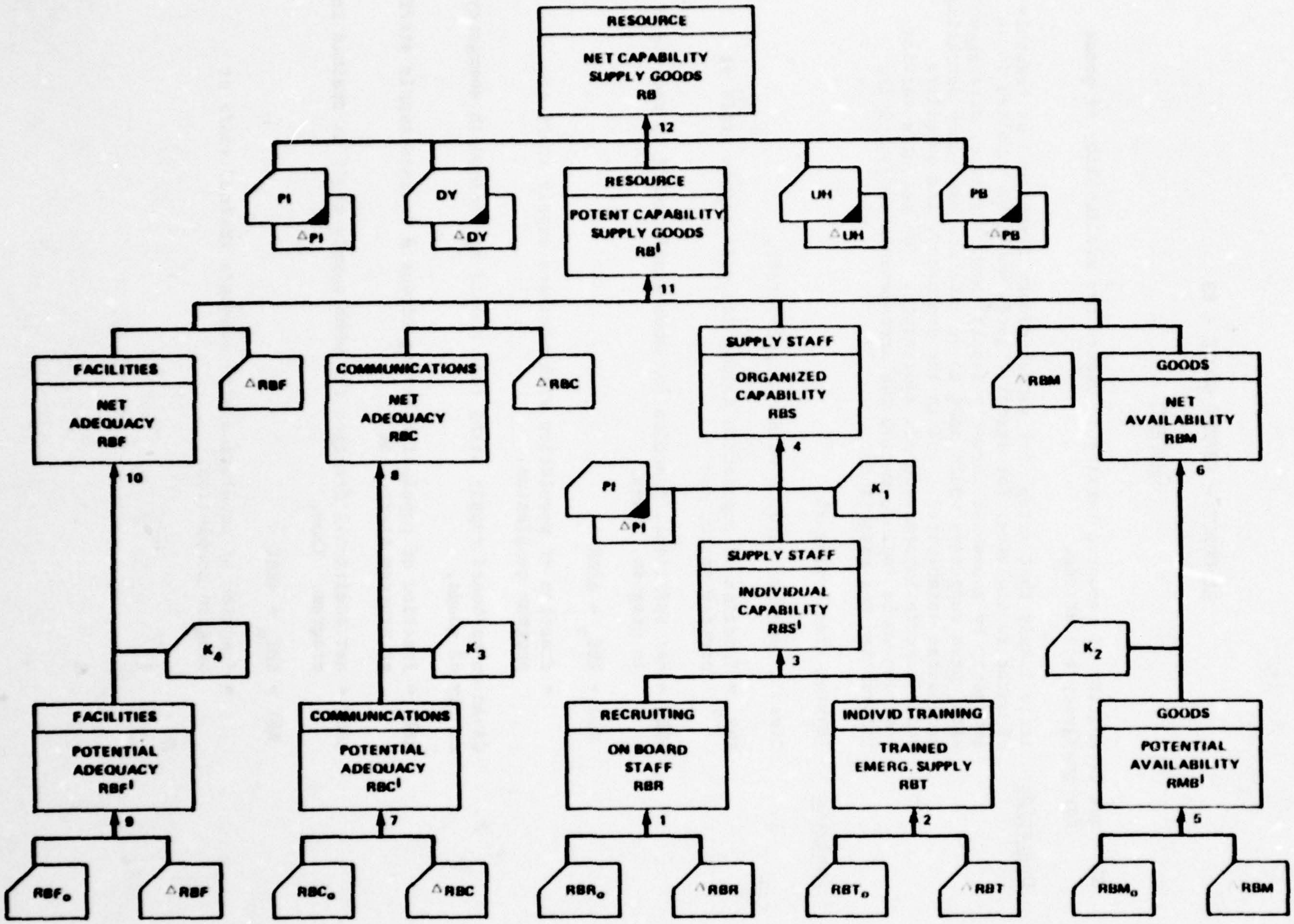
RBT_o = fraction of population having adequate trained supply staff at program start, and

ΔRBT = net additional fraction for whom supply staff is trained in program. Then,

$RBT = RBT_o + \Delta RBT$

= fraction of population with adequate trained staff at program completion.

RESOURCE – SUPPLY GOODS – RB



3. Given that some of the supply staff may be lost because of turnover either before or after being trained, then,

$RBS' = \text{Min } RBR : RBT$

= fraction of population having adequate supply staff individually trained for emergency supply at program completion.

4. Given
(a) that some of the supply staff may be incapacitated by attack effects and
(b) that exercise of the service can enhance staff operating capability,

K_1 = fraction of supply staff effective after attack effects,*

ΔPI = maximum change in supply staff capability between
(a) not having any service exercise and
(b) having fully adequate service exercises, and

PI = net adequacy of exercises of the supply staff in emergency operations. Then,

$$RBS = K_1 \cdot RBS'\{1 - \Delta PI(1 - PI)\}$$

= fraction of population having adequate, effective supply staff after attack.

5. Given that the availability of goods is essential to supply,

RBM_o = fraction of population with assurance of adequate supply of goods for emergency operations at program start, and

ΔRBM = net additional fraction for whom supply of goods is arranged in program. Then,

$$RBM' = RBM_o + \Delta RBM$$

6. Given that goods may be destroyed or access to them denied by attack effects, so that,

---

* $K_1 = 1.0$ for preattack operations.

K_2 = fractional availability of goods after attack effects.* Then,

$RBM = K_2 \cdot RBM'$

= fraction of population with adequate availability of goods after attack.

7. Given that communications are necessary for informing suppliers,

RBC_o = fraction of population having adequate supply communications at program start, and

ΔRBC = net additional fraction for whom communications are procured in program. Then,

$RBC' = RBC_o + \Delta RBC$

= fraction of population having adequate supply communications at program completion.

8. Given that communications may be damaged by attack effects. so that,

K_3 = fractional availability of supply communications after attack effects.* Then,

$RBC = K_3 \cdot RBC'$

= fraction of population having adequate supply communications after attack.

9. Given that facilities may be available for handling of goods for emergency operations,

RBF_o = fraction of population having adequate supply facilities at program start, and

ΔRBF = net additional fraction for whom facilities are procured in program. Then,

$RBF' = RBF_o + \Delta RBF$

= fraction of population having adequate supply facilities at program completion.

---

* K_2 and K_3 = 1.0 for preattack operations.

10. Given that supply facilities may be damaged or access to them denied by attack effects, so that,

K_4 = fractional availability of supply facilities after attack effects.* Then,

$RBF = K_4 \cdot RBF'$

= fraction of population having adequate supply facilities after attack.

11. Given that
(a) availability of goods, communications, and facilities can enhance the operating capability of the supply staff and
(b) it would be limited by the least of them,

ΔRBM = maximum change in supply capability between
(a) not having any goods available and
(b) having a fully adequate supply of goods,

ΔRBC = maximum change in supply capability between
(a) not having any communications and
(b) having fully adequate communications, and

ΔRBF = maximum change in supply capability between
(a) not having any facilities and
(b) having fully adequate facilities. Then,

$$RB' = RBS \cdot \text{Min}\{1-\Delta RBM(1-RBM)\}:\{1-\Delta RBC)1-RBC)\}:\{1-\Delta RBF(1-RBF)\}$$

12. Given that the CD organization should support the resource service,

ΔPI = maximum change in supply capability between
(a) not having any exercise of the CD organization and
(b) having fully adequate exercises,

PI = net adequacy of organization exercises,

ΔDY = maximum change in supply capability between
(a) not having any D&C capability to inform the resource service and
(b) having fully adequate D&C system information capability,

---

*K_4 = 1.0 for preattack operations.

DY = net capability of D&C to inform the resource service,

ΔUH = maximum change in supply capability between
(a) not having any self-help RADEF capability in supply staff and
(b) having fully adequate self-help RADEF capability,

UH = net capability of supply staff for self-help RADEF,

ΔPB = maximum change in supply capability between
(a) not having the emergency supply function treated in operations plans and
(b) having fully adequate treatment, and

PB = net adequacy of treatment of emergency supply in operations plans. Then,

$$RB = RB'\{1 - \Delta PI(1 - PI)\}\{1 - \Delta DY(1 - DY)\}\{1 - \Delta UH(1 - UH)\}\{1 - \Delta PB(1 - PB)\}$$

= fraction of population having adequate capability to supply goods for emergency operations after attack.*

---

* ΔUH = 0 for preattack operations.

D&C - SYSTEM INFORMATION CAPABILITY - DZ

Concept

DZ = Generally, the net capability of local D&C to inform elements of the CD organization as to the situation and as to operational assignments and requirements for cooperation, and so on.

Operation: With respect to system information, D&C has two functions,

1. To serve as an assembly point for information as to the situation and as a source of situation information for other elements of the CD organization, and

2. To serve as the central command for the system, considering problems, deciding what is to be done, and issuing operations orders setting forth operational assignments, cooperation requirements, desired results, and so on. These are functions of the D&C operations staff which is taken here for convenience to include the planning staff. The capability of the operations staff to supply information depends on the ability of the other elements of the organization to supply information to D&C.

Analysis: (System tree overleaf)

1. *Given D&C organizations with operations staff,*

   DZR_o = fraction of population with adequate operations staff at program start, and

   ΔDZR = net additional fraction for whom operations staff are recruited in program. Then,

   $DZR = DZR_o + \Delta DZR$

   = fraction of population having adequate operations staff at program completion.

2. Given an on-board operations staff that should be trained in informing the system,

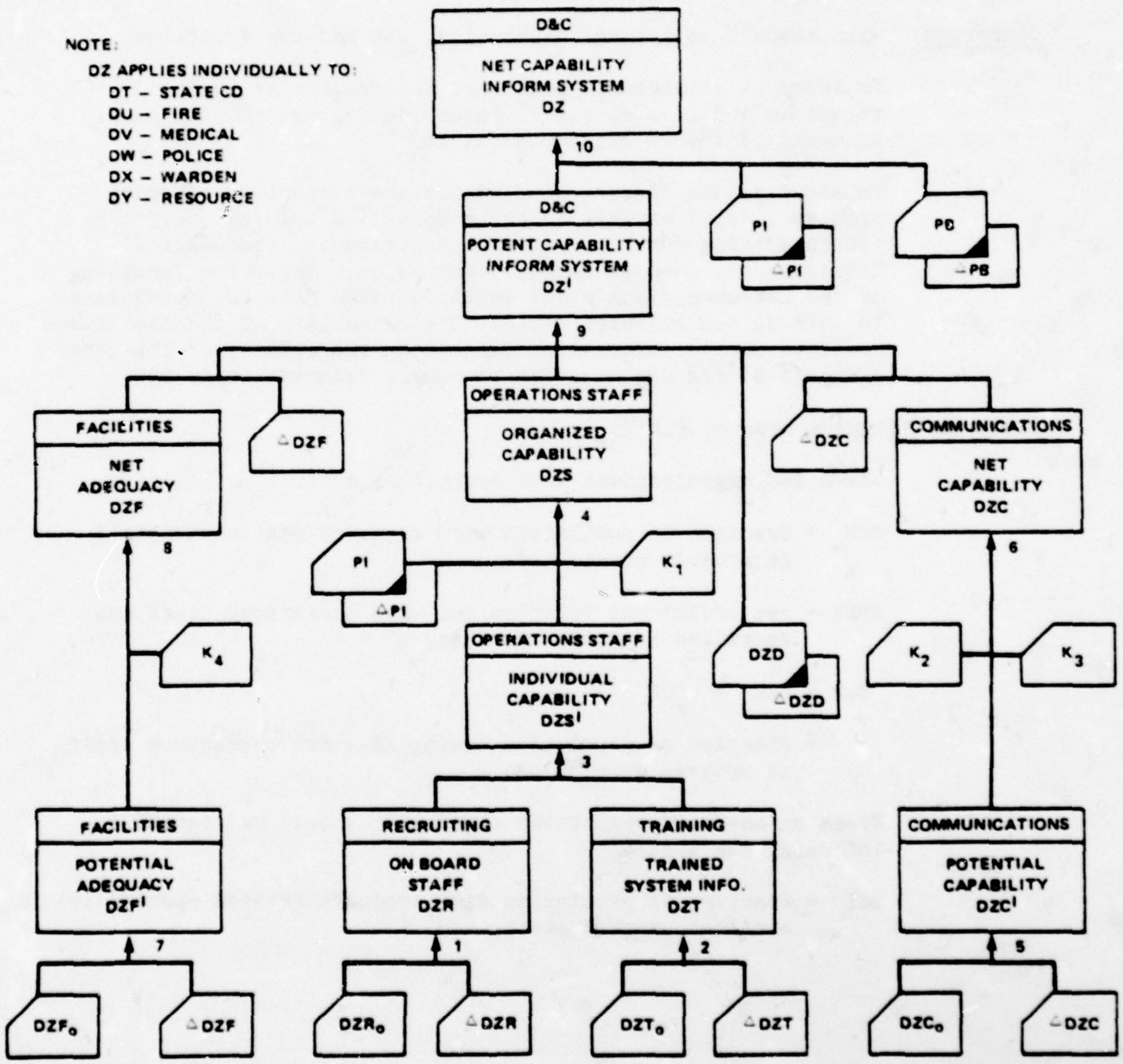
   DZT_o = fraction of population with adequate trained operations staff at program start, and,

D&C – SYSTEM INFORMATION CAPABILITY – DZ

NOTE:

DZ APPLIES INDIVIDUALLY TO:

DT – STATE CD
DU – FIRE
DV – MEDICAL
DW – POLICE
DX – WARDEN
DY – RESOURCE



ΔDZT = net additional fraction for whom operations staff are trained in program. Then,

$$DZT = DZT_o + \Delta DZT$$

= fraction of population with adequate trained operations staff at program completion.

3. Given that some of the operations staff may be lost because of turnover either before or after being trained, then,

$$DZS' = \text{Min } DZR : DZT$$

= fraction of population having adequate operations staff individually trained in system information at program completion.

4. Given
(a) that some of the operations staff may be incapacitated because of attack effects and
(b) that exercise of the staff can enhance its capability

K_1 = fraction of the operations staff effective after attack effects, *

ΔPI = maximum change in informing capability between
(a) not having any staff exercise and
(b) having fully adequate staff exercises, and,

PI = net adequacy of exercises of operations staff. Then,

$$DZS = K_1 \cdot DZS'\{1 - \Delta PI(1 - PI)\}$$

= fraction of population having adequate effective operations staff after attack.

5. Given that informing the system requires communications both to receive and to transmit information,

DZC_o = fraction of population having adequate D&C system communications at program start, and,

---

* K_1 = 1.0 for preattack operations.

ΔDZC = net additional fraction for whom adequate communications are procured in program. Then,

$DZC' = DZC_o + \Delta DZC$

= fraction of population having adequate D&C system communications at program completion.

6. Given that some D&C system communications may be destroyed because of attack effects, so that,

K_2 = fraction of D&C system communications operating after attack effects,* and,

K_3 = *relative reliability of communications*. Then,

$DZC = K_2 \cdot K_3 \cdot DZC'$

= fraction of population having adequate D&C system communications after attack.

7. Given that D&C may have facilities to serve as a work place and communications center,

DZF_o = fraction of population with adequate EOCs at program start, and,

ΔDZF = net additional fraction for whom EOCs are procured in program. Then,

$DZF' = DZF_o + \Delta DZF$

= fraction of population with adequate EOCs at program completion.

8. Given that some EOCs may be destroyed because of attack effects, so that,

K_4 = fraction of EOCs usable after attack effects.* Then,

$DZF = K_4 \cdot DZF'$

= fraction of population having adequate EOCs after attack.

---

* K_2 and K_4 = 1.0 for preattack operations.

9. Given that the informing capability of the operations staff can be enhanced by having communications, facilities, and input information and is limited by the least of these,

ΔDZC = maximum change in capability of operations staff to inform system between
(a) not having any system communications, and,
(b) having fully adequate communications,

ΔDZF = maximum change in capability of operations staff to inform system between
(a) not having any EOCs and
(b) having fully adequate EOCs,

ΔDZD = maximum change in capability of operations staff to inform system between
(a) not having any information input from system and
(b) having fully adequate input information, and,

DZD = net capability of other elements of the CD organization to supply information to D&C. Then,

$$DZ' = DZS \cdot \mathrm{Min}\{1 - \Delta DZC(1 - DZC)\} : \{1 - \Delta DZF(1 - DZF)\} : \{1 - \Delta DZD(1 - DZD)\}$$

= fraction of population with adequate capability of operations staff to inform system if fully supported.

10. Given that the D&C operations staff should be supported,

ΔPI = maximum change in capability to inform system between
(a) not having any exercise of the CD organization and
(b) having fully adequate organization exercises,

PI = net adequacy of CD organization exercises,

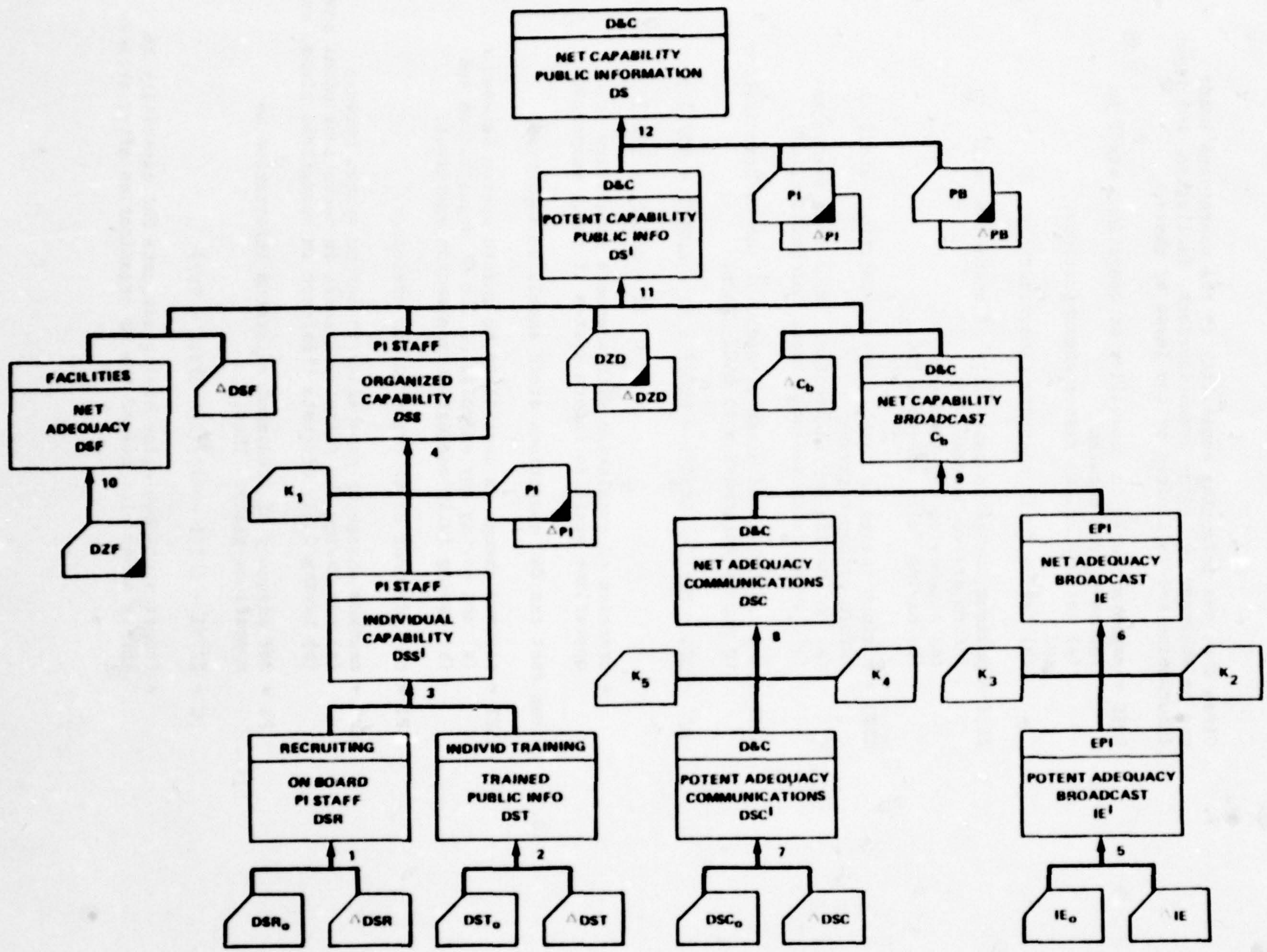
ΔPB = maximum change in capability to inform system between
(a) not having the activity treated in operations plans and
(b) having fully adequate treatment in operations plans, and,

PB = net adequacy of treatment of system information in operations plans. Then,

$$DZ = DZ'\{1 - \Delta PI(1 - PI)\}\{1 - \Delta PB(1 - PB)\}$$

= fraction of population having adequate D&C capability to inform other elements of the CD organization after attack.

D&C – PUBLIC INFORMATION CAPABILITY – DS



D&C - PUBLIC INFORMATION CAPABILITY - DS

Concept

DS = net capability of D&C to broadcast information and guidance to the public via the Emergency Broadcast System.

Operation: Selected broadcast stations are given
(a) protection for their personnel and equipment against attack effects,
(b) emergency power, and
(c) emergency fuel supplies to increase the probability that they will be operable after an attack. Communications from EOCs to these stations are installed. D&C broadcasts information and instructions over these stations.

Analysis:

1. Given D&C organizations with public information staff,

DSR_o = fraction of population having adequate PI staff at start of program, and

ΔDSR = net additional fraction for whom staff is recruited during program. Then,

$DSR = DSR_o + \Delta DSR$

= fraction of population having adequate PI staff at program completion.

2. Given an on-board PI staff that should be trained for Emergency Public Information,

DST_o = fraction of population having adequate PI staff with individual training in public information at start of program, and

ΔDST = net additional fraction for whom staff are trained during program. Then,

$DST = DST_o + \Delta DST$

= fraction of population having adequate trained PI staff at program completion.

3. Given that some of the PI staff can be lost because of turnover either before or after being trained, then,

$DSS' = \text{Min } DSR : DST$

= fraction of population with adequate PI staff individually trained at program completion.

4. Given
(a) that some of the PI staff may be incapacitated because of attack effects and
(b) that staff capability can be enhanced by service exercises,

K_1 = fraction of PI staff effective after attack effects,*

ΔPI = maximum change in PI staff capability between
(a) not having any exercise for training and
(b) having fully adequate exercise for training, and

PI = net adequacy of PI staff exercises for training. Then,

$DSS = K_1 \cdot DSS'\{1 - \Delta PI(1 - PI)\}$

= fraction of population with fully competent effective PI staff after attack.

5. Given selected broadcast stations for the Emergency Broadcast System (EBS),

IE = fraction of population having adequate broadcast station protection at program start, and

ΔIE = net additional fraction given adequate broadcast station protection in program. Then,

$IE' = IE_o + \Delta IE$

= fraction of population having adequate broadcast station protection at program completion.

6. Given
(a) that broadcast stations may not be completely reliable and
(b) that some may be disrupted because of attack effects, so that,

---

* $K_1 = 1.0$ for preattack operations.

K_2 = relative reliability of EBS stations, and

K_3 = fraction of EBS stations operable after attack effects.* Then,

$IE = K_2 \cdot K_3 \cdot IE'$

= fraction of population having operating EBS stations after attack.

7. Given that D&C must be able to communicate from the EOCs to the EBS stations,

DSC_o = fraction of population having adequate D&C communications to EBS at program start, and

ΔDSC = net additional fraction given adequate D&C communications to EBS in program. Then,

$DSC' = DSC_o + \Delta DSC$

= fraction of population having adequate D&C communications to EBS at program completion.

8. Given
(a) that not all EOC - EBS communications will be completely reliable, and
(b) that some of the links may be disrupted by attack effects, so that,

K_4 = relative reliability of communications links, and

K_5 = fraction of communications links operable after attack effects.* Then,

$DSC = K_4 \cdot K_5 \cdot DSC'$

= fraction of population having operating communications from EOCs to EBS stations after attack.

9. Given that the ability of D&C to broadcast over EBS stations requires that both the EOC - EBS communications and the EBS stations be operating, then,

---

* K_3 and K_5 = 1.0 for preattack operations.

C_b = Min IE : DSC

= fraction of population having adequate D&C capability to broadcast over EBS after attack.

10. Given that D&C should have a functioning EOC as a work place and communications center, then,

DSF = DZF (See page B-66)

= fraction of population having adequate EOCs after attack.

11. Given that the capability of the PI staff to broadcast public information depends on having operating stations, EOCs, and input information, and is limited by the least of these,

ΔC_b = maximum change in EPI capability between
(a) not having any EBS stations operating and
(b) having fully adequate EBS capability,

ΔDSF = maximum change in EPI capability between
(a) not having any EOCs and
(b) having fully adequate EOCs,

ΔDZD = maximum change in EPI capability between
(a) not having any input information and
(b) having fully adequate input information, and

DZD = net adequacy of input information. Then,

$$DS' = DSS \cdot Min\{1-\Delta C_b(1-C_b)\}:\{1-\Delta DSF(1-DSF)\}:\{1-\Delta DZD(1-DZD)\}$$

= fraction of population having adequate EPI capability after attack if fully supported.

12. Given that the EPI activity should be supported by exercises and operations plans,

ΔPI = maximum change in EPI capability between
(a) not having any CD organization exercise and
(b) having fully adequate organization exercises,

PI = net adequacy of organization exercises,

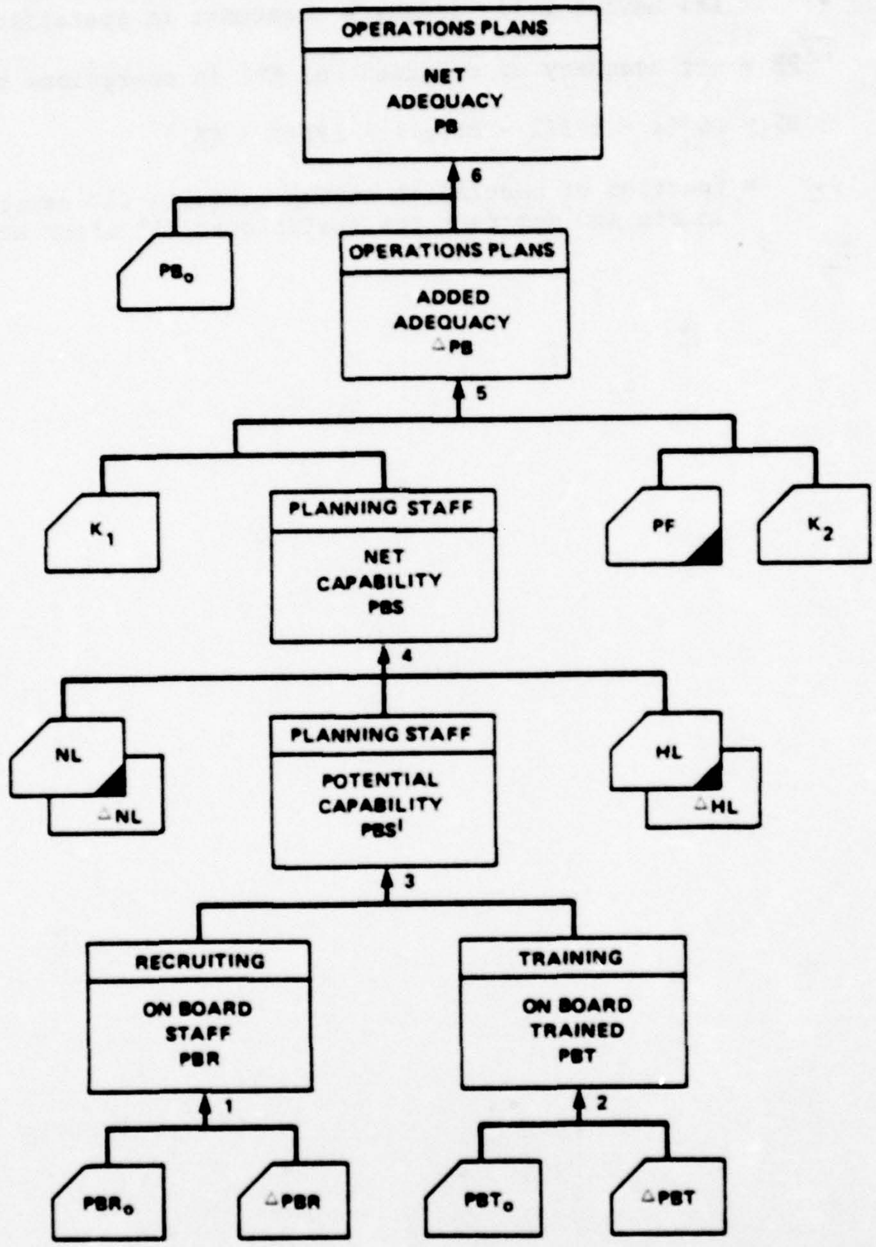
ΔPB = Maximum change in EPI capability between
(a) not having the activity treated in operations plans and
(b) having fully adequate treatment in operations plans, and,

PB = net adequacy of treatment of EPI in operations plans. Then,

$$DS = DS'\{1 - \Delta PI(1 - PI)\}\{1 - \Delta PB(1 - PB)\}$$

= fraction of population having adequate D&C capability to inform and instruct the public over EBS after attack.

OPERATIONS PLANS – PB



OPERATIONS PLANS - PB

Concept

PB = net adequacy of operations plans as a basis for
(1) guiding and controlling the functioning of the operating system and
(2) conducting exercises of the operating system in simulated emergency conditions for training.

Operation: Operations plans are drafted by planners on the staff of the local CD preparedness organization. Optionally, plans can be drafted by other organizations -- government or private -- under contract. Information from Federal and State civil defense is desirable to increase the adequacy of operations plans, for standardization, and for correlation of operations.

Analysis:

1. Given local CD preparedness organizations

   PBR_o = fraction of population having sufficient planners at program start, and

   ΔPBR = net additional fraction for whom planners are recruited in program. Then,

   $PBR = PBR_o + \Delta PBR$

   = fraction of population having sufficient planners.

2. Given on-board planners in local CD preparedness organizations,

   PBT_o = fraction of population having sufficient trained planners at program start, and

   ΔPBT = net additional fraction for whom planners are trained in program. Then,

   $PBT = PBT_o + \Delta PBT$

   = fraction of population having sufficient trained planners.

3. Because of staff turnover, some of the planners may be lost either before or after being trained. Then,

$PBS' = \text{Min } PBR : PBT$

= fraction of population for whom adequate operations plans can be drafted by staff planners if adequately supported by information from Federal and State civil defense and staff is fully productive.

4. Given Federal and State CD organizations,

ΔNL = maximum change in capability of planning staff between (a) not having any information support from States and (b) having fully adequate information support from States,

NL = net adequacy of information support from States,

ΔHL = maximum change in capability of planning staff between (a) not having any information support from Federal and (b) having fully adequate information support from Federal, and

HL = net adequacy of information support from Federal. Then,

$PBS = PBS'\{1-\Delta NL(1-NL)\}\{1-\Delta HL(1-HL)\}$

= fraction of population for whom additional adequate operations plans can be prepared by local staff planners in program if planners were fully productive.

5. Given the option to have some, or all, of operations plans prepared by planning services under contract,

K_1 = relative productivity of planning staff,

PF = fraction of population for whom operations planning service is procured during program, and

K_2 = relative productivity of planning service. Then,

$\Delta PB = K_1 \cdot PBS + K_2 \cdot PF$

= net additional fraction of the population for whom adequate operations plans can be prepared in program.

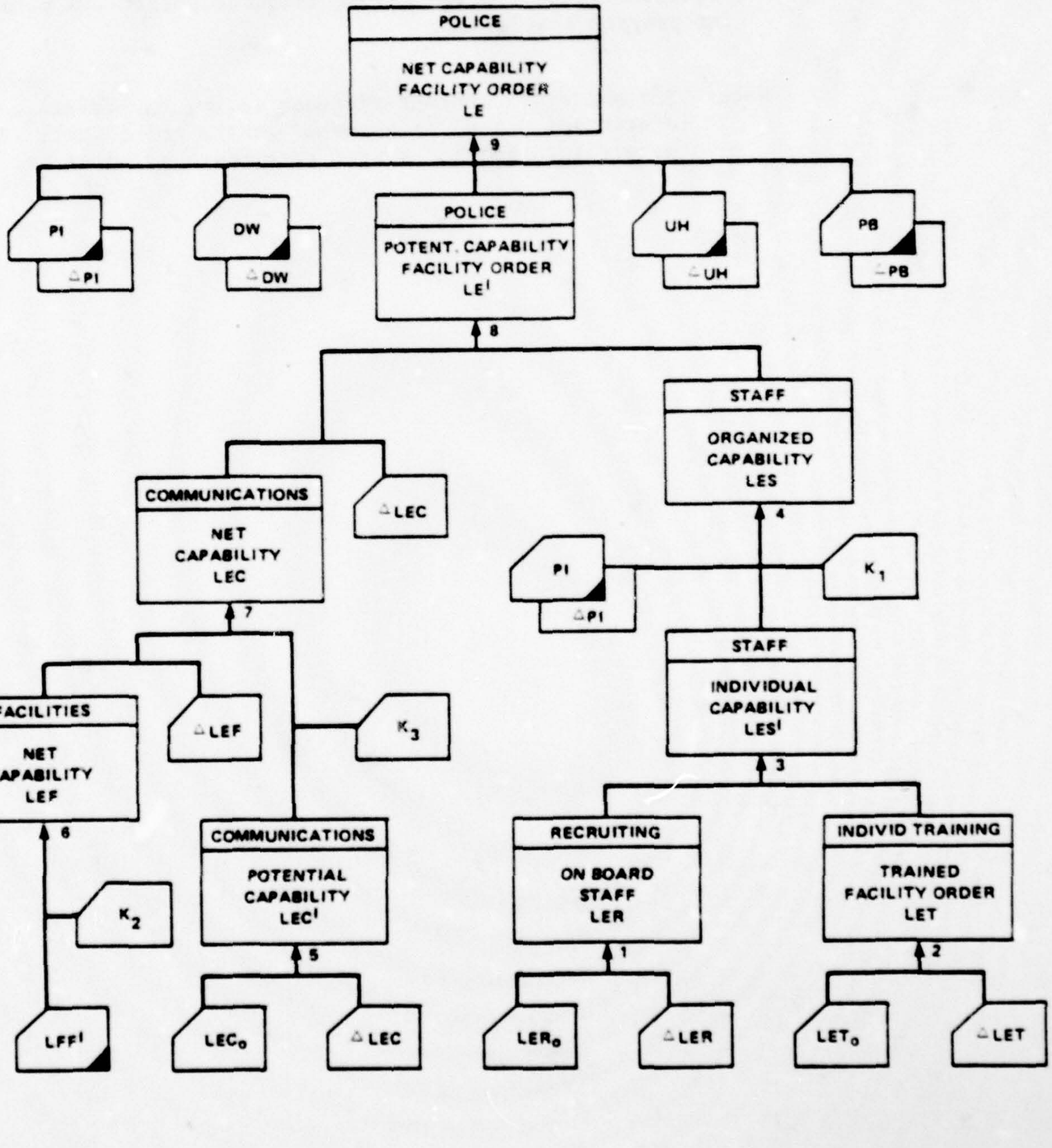
6. Given some, or no, adequate operations plans at start of program, PB_o, then,

$$PB = PB_o + \Delta PB$$

= fraction of population having adequate operations plans at program completion.

Note: The matter of content adequacy (i.e., the coverage of operations plans) is assessed at the point where PB enters into another system tree, such as DS or RK.

POLICE – MAINTAIN FACILITY ORDER – LE



POLICE - MAINTAIN FACILITY ORDER - LE

Concept

LE = net capability of police service to maintain order in or at facilities in which emergency operations are conducted.

Operation: Experience has shown that, under the stress of the emergency, operations can be severely disrupted if order cannot be maintained. It is a function of the police service to maintain order.

Analysis:

1. Given a police service with a facility guard staff,

   LER_o = fraction of population having adequate guard staff at program start, and

   ΔLER = net additional fraction for whom guard staff are recruited in program. Then,

   $LER = LER_o + \Delta LER$

   = fraction of population having adequate guard staff at program completion.

2. Given an on-board guard staff that should be trained in maintaining order in facilities,

   LET_o = fraction of population having adequate trained guard staff at program start, and,

   ΔLET = net additional fraction for whom guard staff are trained in program. Then,

   $LET = LET_o + \Delta LET$

   = fraction of population having adequate trained facility guard staff at program completion.

3. Given that some of the guard staff may be lost because of turnover either before or after being trained, then,

$LES' = \text{Min } LER : LET$

= fraction of population having adequate facility guard staff individually trained in maintaining order at program completion.

4. Given
(a) that some of the guard staff may be incapacitated by attack effects and
(b) that exercise of the service can enhance staff capability,

K_1 = fraction of facility guard staff effective after attack effects,*

ΔPI = maximum change in guard staff capability between
(a) not having any service exercise and
(b) having fully adequate service exercise, and

PI = net adequacy of exercise of facility guard staff. Then,

$LES = K_1 \cdot LES'\{1 - \Delta PI(1 - PI)\}$

= fraction of population having adequate, effective facility guard staff after attack.

5. Given that facility guards need communications within the service,

LEC_o = fraction of population with adequate guard communications at program start, and

ΔLEC = net additional fraction for whom guard communications are procured in program. Then,

$LEC' = LEC_o + \Delta LEC$

= fraction of population having adequate guard communications at program completion.

---

* $K_1 = 1.0$ for preattack operations.

6. Given
(a) that police communications traditionally pass through dispatchers in police stations, and
(b) that some of these facilities may be damaged or access to them denied because of attack effects,

LFF' = fraction of population having adequate police facilities at program completion, (See page B-54), and,

K_2 = fraction of police facilities available after attack effects.* Then,

$$LEF = K_2 \cdot LFF'$$

= fraction of population having adequate police facilities available after attack.

7. Given that
(a) some police communications may be destroyed because of attack effects and
(b) that the capability of police communications can depend on having facilities,

K_3 = fraction of police communications available after attack effects, * and,

ΔLEF = maximum change in police communications capability between
(a) not having any facilities and
(b) having fully adequate facilities. Then,

$$LEC = K_3 \cdot LEC'\{1 - \Delta LEF(1 - LEF)\}$$

= fraction of population having adequate facility guard communications after attack.

8. Given that communications can enhance the operating capability of facility guards, and,

ΔLEC = maximum change in facility guard capability between
(a) not having any communications and
(b) having fully adequate communications. Then,

---

* K_2 and K_3 = 1.0 for preattack operations.

$LE' = LES\{1 - \Delta LEC(1 - LEC)\}$

= fraction of population having adequate facility guard capability to maintain order if fully supported.

9. Given that the CD organization should support the police service facility guards,

ΔPI = maximum change in capability to maintain order between (a) not having any exercise of the CD organization and (b) having fully adequate exercises,

PI = net adequacy of exercises of CD organization,

ΔDW = maximum change in capability to maintain order between (a) not having any D&C capability to inform the police service and (b) having fully adequate D&C system information capability,

DW = net capability of D&C to inform the police service,

ΔUH = maximum change in capability to maintain order between (a) not having any facility guard capability for self-help RADEF and (b) having fully adequate self-help RADEF capability,

UH = net capability of facility guards for self-help RADEF,

ΔPB = maximum change in capability to maintain order between (a) not having the activity treated in operations plans and (b) having fully adequate treatment in operations plans, and

PB = net adequacy of treatment of maintenance of facility order in operations plans. Then,

$$LE = LE'\{1 - \Delta PI(1 - PI)\}\{1 - \Delta DW(1 - DW)\}\{1 - \Delta UH(1 - UH)\}\{1 - \Delta PB(1 - PB)\}$$

= fraction of population having adequate police service capability to maintain order in or at facilities where emergency operations are being conducted after attack.*

---

* $\Delta UH = 0$ for preattack operations.

PUBLIC PREPAREDNESS - CRISIS RELOCATION - I_c

Concept

I_c = net effectiveness of CD organization in educating the public before a crisis relocation -- as in a surge period -- to prepare them for relocating including such matters as: location of host areas; plans and preparations for reception, care, and sheltering of all those relocating; plans and preparations for commuting and protection of essential workers; and the details of the movement plan with specific emphasis on actions the public must take.

Operation: The public preparedness activity is primarily a function of D&C operating by agreement through the media, other government and private agencies, and so on. Within the CD organization the activity can also be conducted by the emergency services -- fire, police, and warden -- who would supplement the D&C efforts. Each of these elements of the organization would use information materials prepared by the EPI staff of the preparedness organization.

Analysis: (System tree overleaf)

1. Given local CD organizations,

DNR_o = fraction of population having adequate D&C public information staff at start of program, and

ΔDNR = net additional fraction for whom public information staff is recruited during program. Then,

$DNR = DNR_o + \Delta DNR$

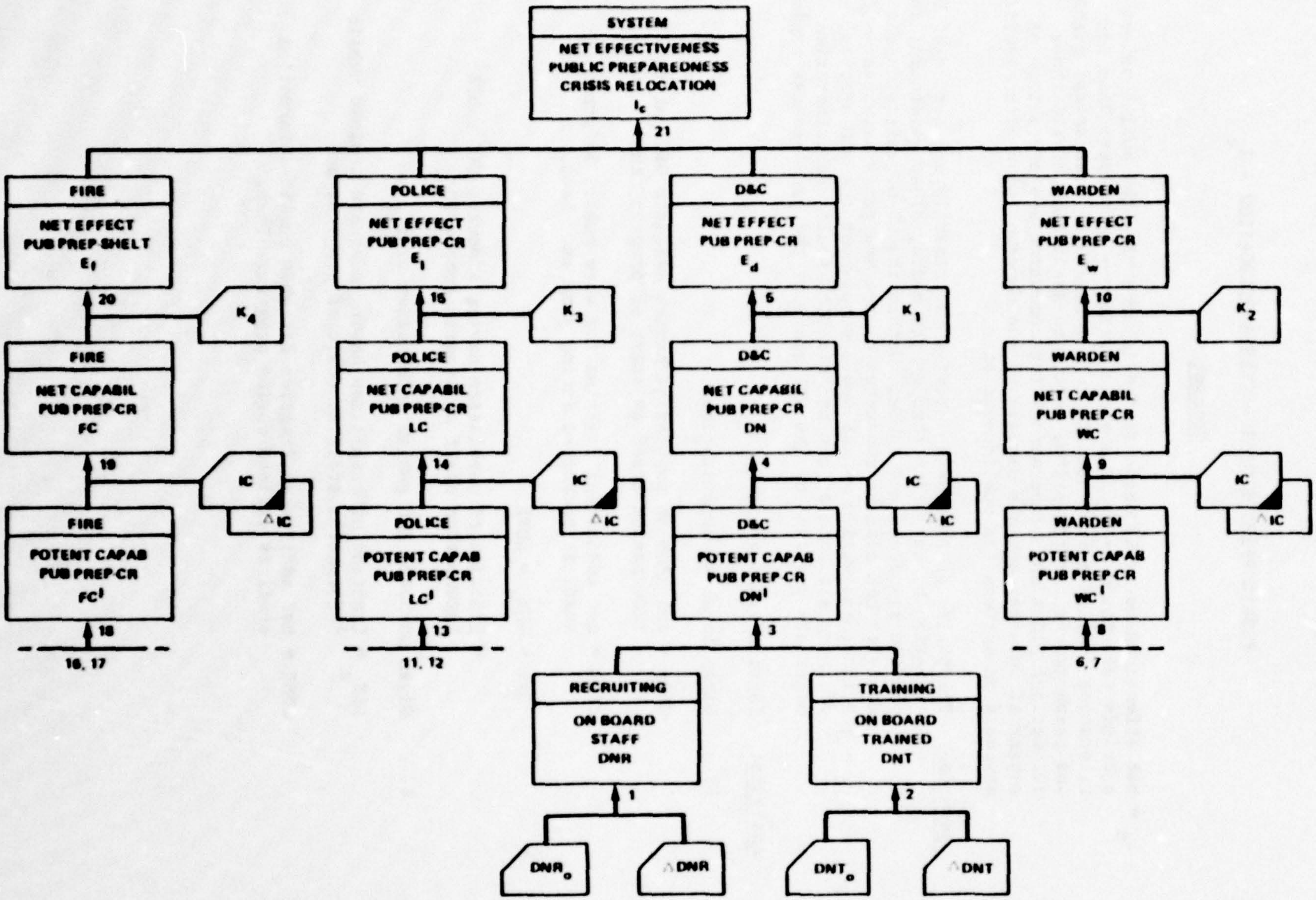
= fraction of population having adequate D&C public information staff at program completion.

2. Given on-board D&C public information staff,

DLT_o = fraction of population having adequate trained public information staff at start of program, and

ΔDNT = net additional fraction for whom public information staff is trained during program. Then,

PUBLIC PREPAREDNESS-CRISIS RELOCATION – I_c



$DNT = DNT_o + \Delta DNT$

= fraction of population having adequate trained public information staff at program completion.

3. Because some of the public information staff may be lost through staff turnover either before or after training,

$DN' = \text{Min } DNR : DNT$

= fraction of population for whom D&C public information staff can adequately prepare the public for crisis relocation given fully adequate public information materials.

4. Given a capable D&C public information staff and information materials,

ΔIC = maximum change in capability of D&C public information staff to prepare public for crisis relocation between (a) not having any EPI CR information preparations, and (b) having fully adequate EPI preparations, and

IC = net adequacy of EPI preparations = fraction of population for whom preparations have been made at program completion. Then,

$DN = DN'\{1-\Delta IC(1-IC)\}$

= fraction of population with capable D&C public information staff and available information materials.

5. Given staff and materials, and

K_1 = relative effectiveness of D&C public information staff in preparing public. Then,

$E_d = K_1 \cdot DN$

= net effectiveness of D&C public information staff in preparing public for crisis relocation.

And, similarly

6. $WCR = WCR_o + \Delta WCR$

7. $WCT = WCT_o + \Delta WCT$

8. $WC' = \text{Min } WCR : WCT$

9. $WC = WC'\{1 - \Delta IC(1 - IC)\}$

10. $E_w = K_2 \cdot WC$

= net effectiveness of warden service in preparing public for crisis relocation.

11. $LCR = LCR_o + \Delta LCR$

12. $LCT = LCT_o + \Delta LCT$

13. $LC' = \text{Min } LCR : LCT$

14. $LC = LC'\{1 - \Delta IC(1 - IC)\}$

15. $E_\ell = K_3 \cdot LC$

= net effectiveness of police service in preparing public for crisis relocation.

16. $FCR = FCR_o + \Delta FCR$

17. $FCT = FCT_o + \Delta FCT$

18. $FC' = \text{Min } FCR : FCT$

19. $FC = FC'\{1 - \Delta IC(1 - IC)\}$

20. $E_f = K_4 \cdot FC$

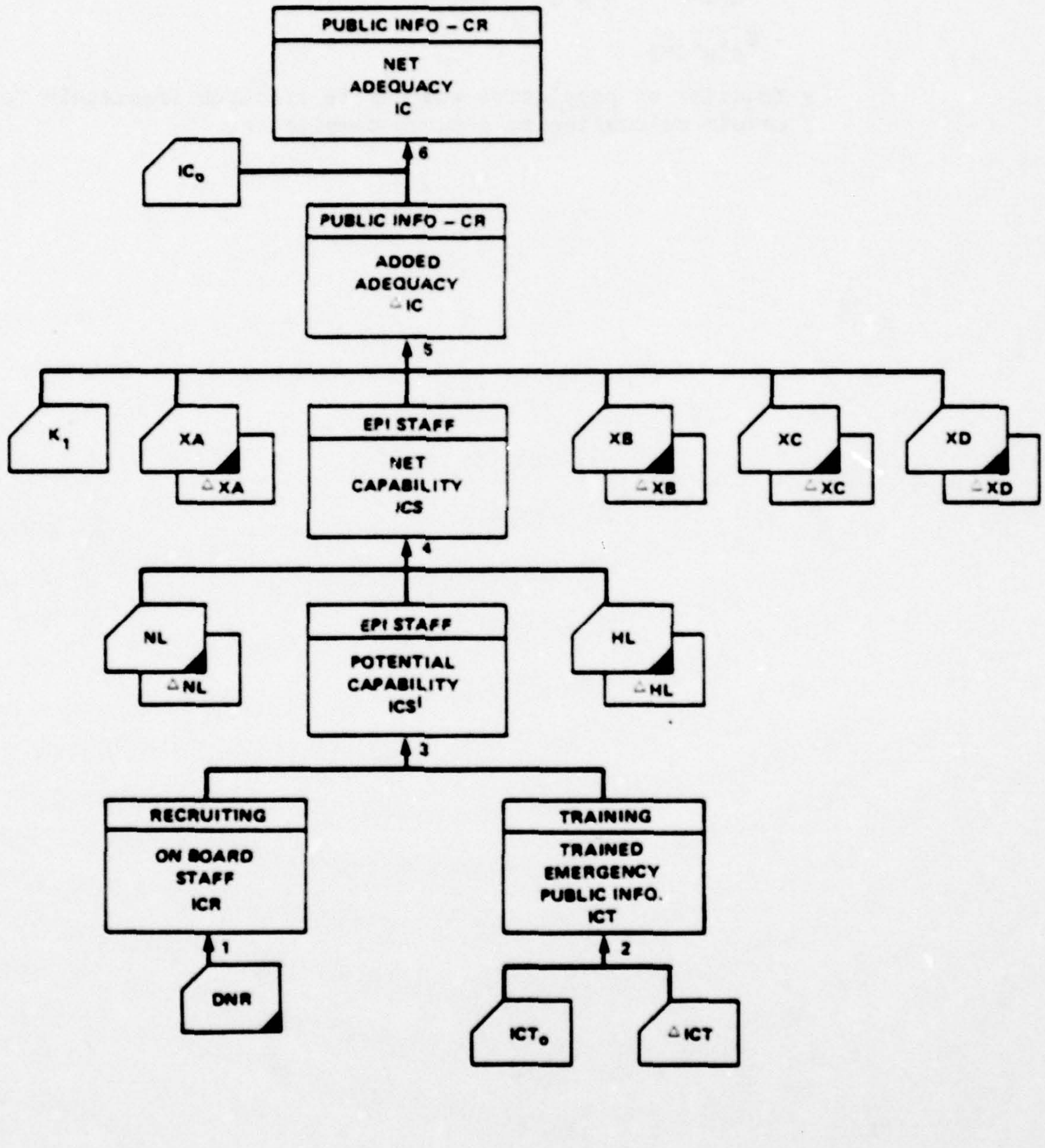
= net effectiveness of fire service in preparing public for crisis relocation

21. Given
(1) these four alternative means of preparing the public for crisis relocation, and
(2) each person subject to being prepared only once,

$$
\begin{aligned}
I_c = {} & E_d + E_w + E_\ell + E_f \\
& - E_dE_w - E_dE_\ell - E_dE_f - E_wE_\ell - E_wE_f - E_\ell E_f \\
& + E_dE_wE_\ell + E_dE_wE_f + E_wE_\ell E_f \\
& - E_dE_wE_\ell E_f
\end{aligned}
$$

= fraction of population who can be prepared adequately for crisis relocation at program completion.

PUBLIC INFORMATION MATERIALS – CRISIS RELOCATION – IC



PUBLIC INFORMATION MATERIALS - CRISIS RELOCATION - IC

Concept

IC = net adequacy of informational materials prepared for use in public preparedness education for crisis relocation including
(a) location of host areas
(b) plans and preparations for reception, care, and sheltering of all those relocating
(c) plans and preparations for commuting and protection of essential workers, and
(d) details of the movement plan with specific emphasis on actions the public must take.

Operation: EPI informational materials are prepared by personnel of an EPI staff element of the preparedness system organization trained for assignment to their positions and arrangements are concluded for dissemination of these materials. Information for these materials can be supplied from Crisis Relocation Plans.

Analysis:

1. Given EPI staff in local CD preparedness organizations so that,

   ICR = DNR = fraction of population having adequate EPI staff at program completion (See page B-83).

2. Given on-board EPI staff,

   ICT_o = fraction of population having adequate trained EPI staff at program start, and

   ΔICT = net additional fraction for whom EPI staff is trained during program. Then,

   $ICT = ICT_o + \Delta ICT$

   = fraction of population with adequate trained EPI staff.

3. Because of staff turnover, some of the EPI staff may be lost either before or after training. Then,

$ICS' = \text{Min } ICR : ICT$

= fraction of population for whom adequate emergency public information materials on crisis relocation can be prepared by EPI staff given fully adequate support.

4. Given a potential local EPI staff capability and Federal and State CD organization,

ΔHL = maximum change in capability of EPI staff between
(a) not having any Federal guidance and
(b) having fully adequate Federal guidance,

HL = net adequacy of Federal guidance,

ΔNL = maximum change in capability of EPI staff between
(a) not having any State guidance and
(b) having fully adequate State guidance, and

NL = net adequacy of State guidance. Then,

$$ICS = ICS'\{1 - \Delta HL(1 - HL)\}\{1 - \Delta NL(1 - NL)\}$$

= fraction of population having EPI staff capable of producing instructional materials for public preparedness for crisis relocation.

5. Given a capable EPI staff and Crisis Relocation Plans,

K_1 = relative productivity of EPI staff,

ΔXA = maximum change in production of informational materials between
(a) not having any crisis relocation movement plans and
(b) having fully adequate crisis relocation movement plans,

XA = net adequacy of crisis relocation movement plans,

ΔXB = maximum change in production of informational materials between
(a) not having any crisis relocation reception and care plans and
(b) having fully adequate crisis relocation reception and care plans,

XB = net adequacy of crisis relocation reception and care plans,

ΔXC = maximum change in production of informational materials between
(a) not having any crisis relocation plans for revising supply channels and
(b) having fully adequate crisis relocation plans for revising supply channels,

XC = net adequacy of crisis relocation plans for revising supply channels,

ΔXD = maximum change in production of informational materials between
(a) not having any crisis relocation plans for commuting essential workers and
(b) having fully adequate crisis relocation plans for commuting essential workers, and

XD = net adequacy of crisis relocation plans for commuting essential workers. Then,

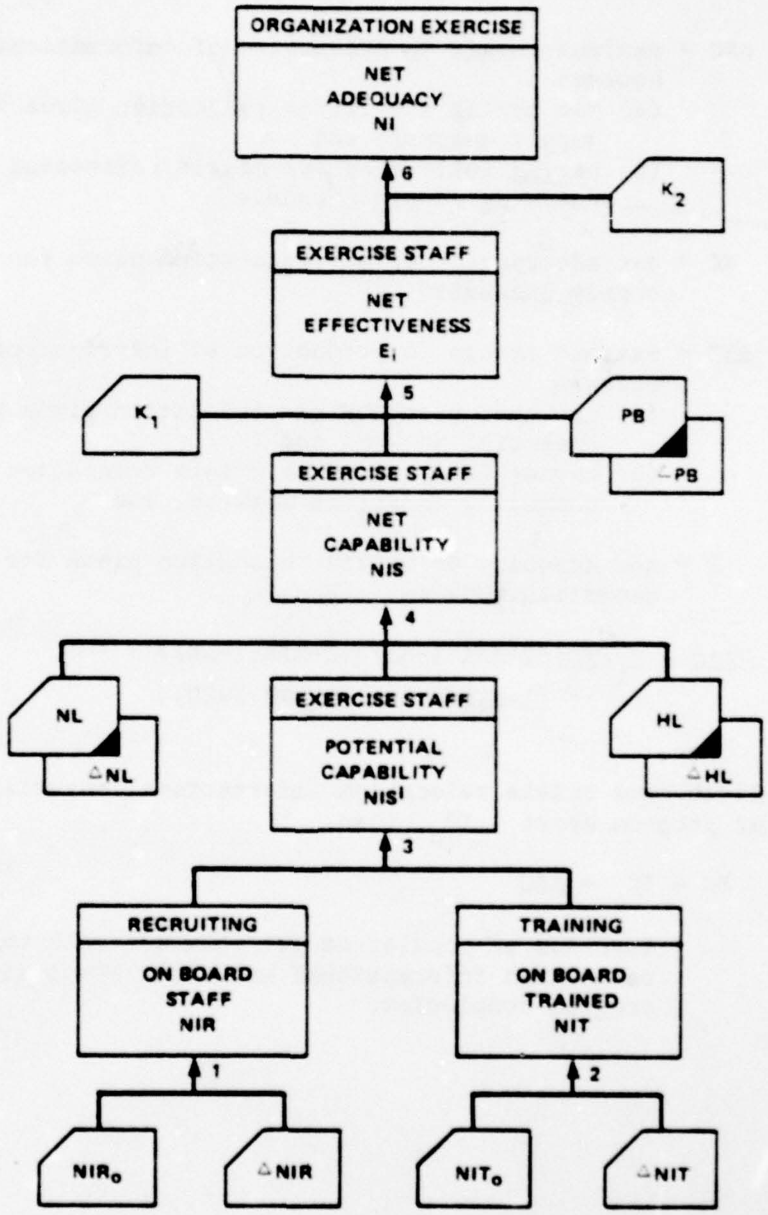
$$\Delta IC = K_1 \cdot ICS\{1-\Delta XA(1-XA)\}\{1-\Delta XB(1-XB)\}\{1-\Delta XC(1-XC)\}\{1-\Delta XD(1-XD)\}$$

6. Given some crisis relocation informational materials available at program start - IC_o, then,

$$IC = IC_o + \Delta IC$$

= fraction of population for whom adequate crisis relocation informational materials are available at program completion.

ORGANIZATION EXERCISE – NI



ORGANIZATION EXERCISE - NI

Concept

NI = net adequacy of exercising the State CD operating system organization in emergency operations for training in operating as an organization.

Operation: An exercise staff of the State CD preparedness organization prepares and conducts exercises of the emergency operating organization in simulated emergency conditions, either of a single service or of combinations of services including the whole operating organization for training in emergency operations. Exercises are based on operations plans. Information from Federal and State civil defense is desirable to increase the adequacy of the exercises especially in exercise methods and realism of the simulation.

Analysis:

1. Given State CD preparedness organizations,

NIR_o = fraction of population having sufficient exercise staff at start of program, and,

ΔNIR = net additional fraction for whom exercise staff is recruited in program. Then,

$NIR = NIR_o + \Delta NIR$

= fraction having sufficient exercise staff.

2. Given on-board exercise staff in State CD preparedness organizations,

NIT_o = fraction of population having trained exercise staff at start of program, and

ΔNIT = net additional fraction for whom exercise staff is trained in program. Then,

$NIT = NIT_o + \Delta NIT$

= fraction of population having trained exercise staffs.

3. Because of staff turnover, some of the exercise staff may be lost, before or after training. Then,

NIS' = Min NIR : NIT

= fraction of population for whom adequate organization exercises can be conducted if the exercise staff is fully supported by information from Federal and State and is fully effective and if operations plans are fully adequate.

4. Given Federal and State CD organizations,

ΔNL = maximum change in capability of exercise staff between (a) not having any information support from State and (b) having fully adequate information support from State,

NL = net adequacy of information support from State,

ΔHL = maximum change in capability of exercise staff between (a) not having any information support from Federal and (b) having fully adequate information support from Federal, and

HL = net adequacy of information support from Federal. Then,

$$NIS = NIS'\{1-\Delta NL(1-NL)\}\{1-\Delta HL(1-HL)\}$$

= fraction of the population for whom organization exercises can be conducted if exercise staffs are fully effective and operations plans are fully adequate.

5. Given on-board State exercise staffs,

K_1 = relative effectiveness of exercise staff in training,

ΔPB = maximum change in effectiveness of exercise staff between (a) not having any operations plans and (b) having fully adequate operations plans, and

PB = net adequacy of operations plans. Then,

$E_1 = K_1 \cdot NIS\{1 - \Delta PB(1 - PB)\}$

= fraction of population for whom effective organization exercises can be conducted in latter years of program.

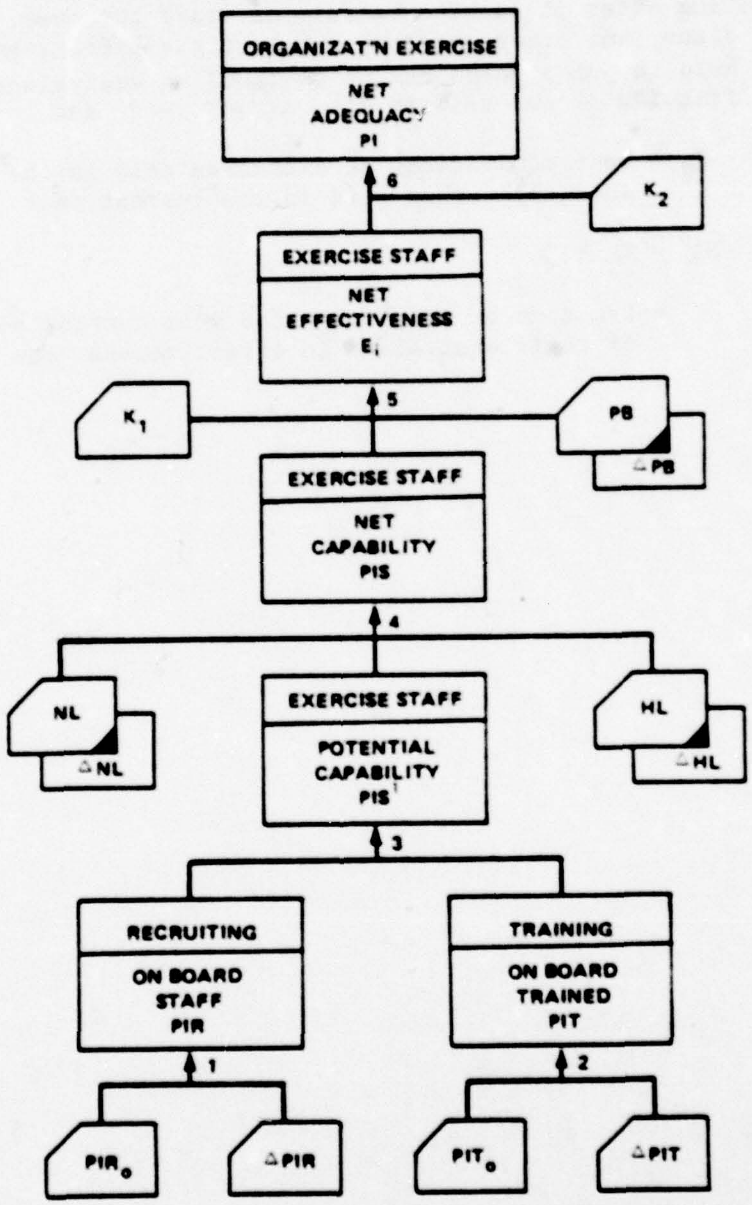
6. Given that the effectiveness of an exercise decreases with time after it is held because of staff turnover, changes in plans, and other reasons, and that the effectiveness of exercises held in prior years can be assigned an equivalence that is some fraction of one held in the current year, and

K_2 = mean equivalence of exercises held in the program to an equal number held in the current year. Then,

$NI = K_2 \cdot E_1$

= fraction of population for whom current year exercises, or their equivalent in effectiveness, can be held.

ORGANIZATION EXERCISE – PI



ORGANIZATION EXERCISE - PI

Concept

PI = net adequacy of exercising the local CD operating system organization in emergency operations for training in operating as an organization.

Operation: An exercise staff of the local CD preparedness organization prepares and conducts exercises of the emergency operating organization in simulated emergency conditions, either of a single service or of combinations of services including the whole operating organization for training in emergency operations. Exercises are based on operations plans. Information from Federal and State civil defense is desirable to increase the adequacy of the exercises especially in exercise methods and realism of the simulation.

Analysis:

1. Given local CD preparedness organizations,

   PIR_o = fraction of population having sufficient exercise staff at start of program, and,

   ΔPIR = net additional fraction for whom exercise staff is recruited in program. Then,

   $$PIR = PIR_o + \Delta PIR$$

   = fraction having sufficient exercise staff.

2. Given on-board exercise staff in local CD preparedness organizations,

   PIT_o = fraction of population having trained exercise staff at start of program, and,

   ΔPIT = net additional fraction for whom exercise staff is trained in program. Then,

   $$PIT = PIT_o + \Delta PIT$$

   = fraction of population having trained exercise staffs.

3. Because of staff turnover, some of the exercise staff may be lost, before or after training. Then,

$PIS' = \text{Min } PIR : PIT$

= fraction of population for whom adequate organization exercises can be conducted if the exercise staff is fully supported by information from Federal and State and is fully effective and if operations plans are fully adequate.

4. Given Federal and State CD organizations,

ΔNL = maximum change in capability of exercise staff between (a) not having any information support from State and (b) having fully adequate information support from State,

NL = net adequacy of information support from State,

ΔHL = maximum change in capability of exercise staff between (a) not having any information support from Federal and (b) having fully adequate information support from Federal, and,

HL = net adequacy of information support from Federal. Then,

$$PIS = PIS'\{1 - \Delta NL(1 - NL)\}\{1 - \Delta HL(1 - HL)\}$$

= fraction of the population for whom organization exercises can be conducted if exercise staffs are fully effective and operations plans are fully adequate.

5. Given on-board local exercise staffs,

K_1 = relative effectiveness of exercise staff in training,

ΔPB = maximum change in effectiveness of exercise staff between (a) not having any operations plans and, (b) having fully adequate operations plans, and,

PB = net adequacy of operations plans. Then,

$E_i' = K_1 \cdot PIS\{1 - \Delta PB(1 - PB)\}$

= fraction of population for whom effective organization exercises can be conducted in latter years of program.

6. Given that the effectiveness of an exercise decreases with time after it is held because of staff turnover, changes in plans, and other reasons, and that the effectiveness of exercises held in prior years can be assigned an equivalence that is some fraction of one held in the current year, and

K_2 = mean equivalence of exercises held in the program to an equal number held in the current year. Then,

$PI = K_2 \cdot E_i'$

= fraction of population for whom current year exercises, or their equivalent in effectiveness, can be held.

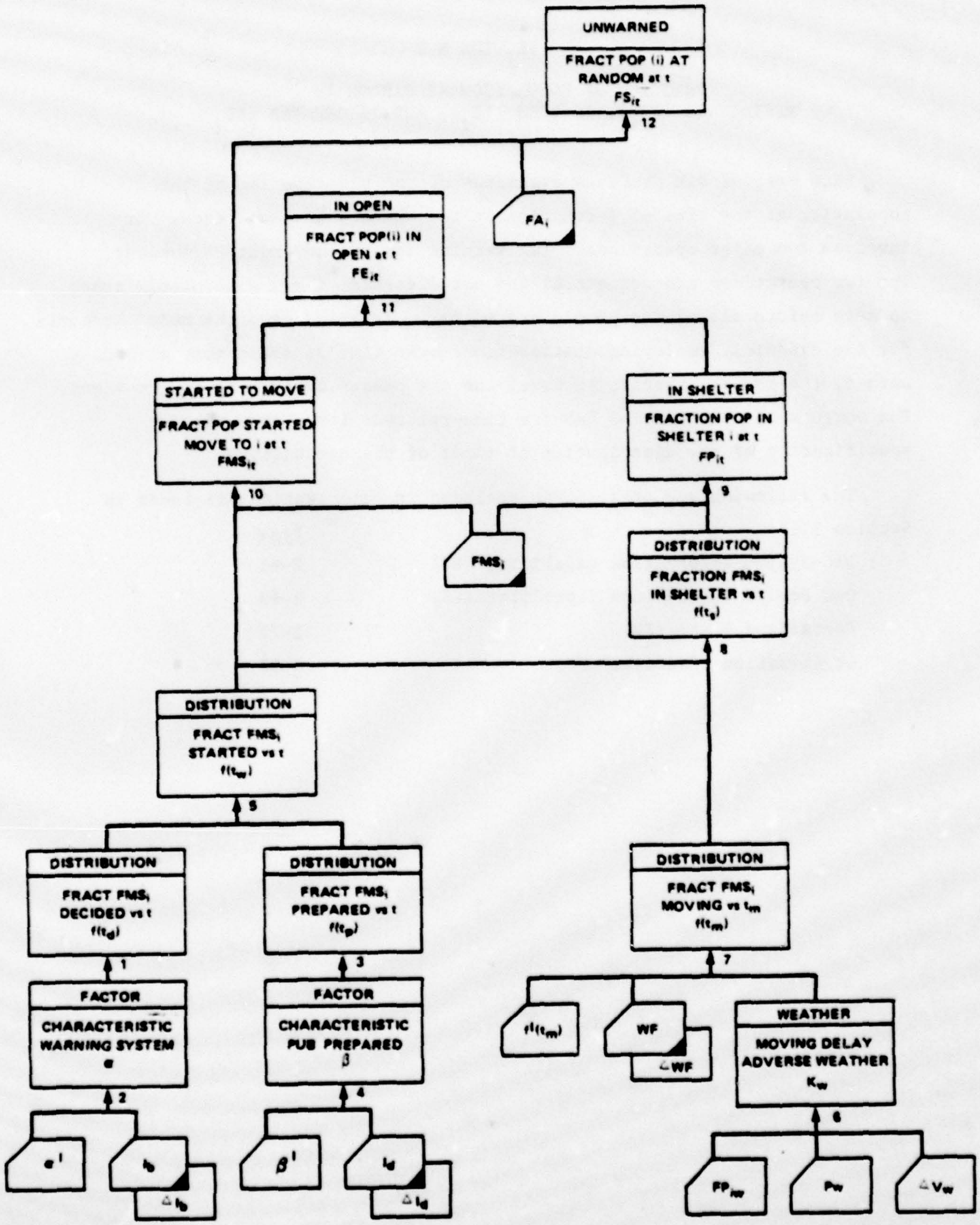
SECTION B.2

FRACTION OF POPULATION AT RANDOM IN RESIDENCES (FS_i), IN OPEN (FE_i), AND IN SHELTER (FP_i)

This part of PAM produces estimates of the distribution of the population at the time of detonation of the weapons in the attack. It involves two major operations: (a) warning and (b) movement to shelter. The two operations are sequential but not discrete; i.e., some people start to move before all of the people are warned. In this case, the model accounts for the dynamics, employing distributions over time of the number of people warned, the number starting to move, and the number completing the movement. The outputs of this part of PAM are time-related; i.e., they require specification of the distribution of times of the detonations.

The following elements of PAM included in this section are found in Section B.1:

FRACTION OF POPULATION AT RANDOM IN RESIDENCES (FS_i), IN OPEN (FE_i), AND IN SHELTER (FP_i)



FRACTION AT RANDOM IN RESIDENCES - FS_i
FRACTION IN OPEN - FE_i
FRACTION IN SHELTER - FP_i

Concept

FS_i = fraction of the total population who are assigned to shelter class i and who are distributed at random in residences at time of attack,

FE_i = fraction of the total population caught in open at time of attack while moving to shelter class i,

FP_i = fraction of the total population in shelter class i at the time of attack.

Operation: A warning system provides an alerting signal plus a confirming message over radio and TV. This warning is supplemented by efforts of the CD organization and by members of the public. Prior to the warning, emergency public information activities attempt to prepare the public for warning and for going to shelter. As they are warned and as they complete their preparations, some of the people start to move to shelter and as they arrive they enter the shelters. Some of the people decide not to go to shelter. When the attack occurs, some fraction of the people are in shelter, another fraction is at random in residences, and, if the attack occurs before all of those going to shelter have entered the shelters, a third fraction is caught in the open.

Analysis:

1. Given a warning system to which people respond at different rates, some requiring longer to decide to go to shelter than others,

   t = period between start of alert and the time of interest, and

   α = a characteristic of the warning system that depends on the design of the system and the preparedness of the public for warning. Then,

   $f(t_d) = 1 - e^{-\alpha t}(\alpha t + 1)$

   = fraction of those who intend to go to shelter who have decided to go by time t.

2. Given a warning and emergency public information activities to prepare the public for warning.

α' = value of α if public is fully prepared,

ΔI_b = maximum change in α between
(a) not having any public preparedness EPI and
(b) having fully effective EPI, and

I_b = net effectiveness of public preparedness for warning. Then,

$$\alpha = \alpha'\{1 - \Delta I_b(1 - I_b)\}$$

= value of α to be used in calculating $f(t_d)$.

3. Given that people will prepare to go at different rates after being warned,

t = period between start of alert and time of interest, and

β = a characteristic of the public that depends on their preparedness for going to shelter. Then,

$$f(t_p) = 1 - e^{-\beta t}(\beta t + 1)$$

= fraction of those who intend to go to shelter who are prepared to start by time t.

4. Given a warning and EPI activities to prepare the public for going to shelter,

β' = value of β if public is fully prepared,

ΔI_d = maximum change in β between
(a) not having any public preparedness and
(b) having fully effective EPI, and

I_d = net effectiveness of public preparedness for shelter activities. Then,

$$\beta = \beta'\{1 - \Delta I_d(1 - I_d)\}$$

= value of β to be used in calculating $f(t_p)$

5. Given that $f(t_d)$ and $f(t_p)$ are dependent probability distributions, they cannot simply be added but must be convoluted, then,

$f(t_w) = f(t_d)$ convoluted with $f(t_p)$

= fraction of those who intend to go to shelter who have started to move by time t.

6. Given that
(a) the time it takes for people to move to shelter depends on the distance they must move and their walking speed and
(b) walking speed can be affected by adverse weather,

FP_{iw} = fraction of the population of shelter class i who could be affected by adverse weather,

P_w = probability of occurrence of adverse weather, and

ΔV_w = fractional reduction in walking speed because of adverse weather. Then,

$K_w = FP_{iw} \cdot P_w(1 - \Delta V_w)$

= fractional reduction in the fraction of those moving to shelter who would arrive by time t_m after starting to move.

7. Given that the rate at which people move to shelter can depend on the capability of the warden service for managing the movement,

$f'(t_m)$ = fraction of those moving to shelter who could arrive within time t_m if warden service were fully capable and weather were favorable,

ΔWF = maximum change in $f(t_m)$ between
(a) not having any warden service capability and
(b) having fully adequate warden service capability, and

WF = net capability of warden service for managing movement to shelter. Then

$f(t_m) = f'(t_m)(1 - K_w)\{1 - \Delta WF(1 - WF)\}$

= fraction of those moving to shelter who would arrive in shelter within time t_m after starting to move.

8. Given that $f(t_w)$ and $f(t_m)$ are dependent probability distributions, they cannot simply be added but must be convoluted, then,

$f(t_s) = f(t_w)$ convoluted with $f(t_m)$

= fraction of population who intend to go to shelter class i who are in shelter by time t after start of alert.

9. Given that the fraction of the population actually in shelter class i at time t depends on the fraction who decide to go, and,

FMS_i = fraction of the population who decide to go to shelter class i. Then,

$FP_{it} = FMS_i \cdot f(t_s)$

= fraction of population in shelter class i at time t after start of alert.

10. Given that the fraction of the population who have started to move to shelter class i by time t depends on the fraction who decide to go, Then,

$FMS_{it} = FMS_i \cdot f(t_w)$

= fraction of population who have started to move to shelter class i by time t after start of alert.

11. Given that the fraction of the population who have started to move to shelter class i by time t less the fraction in shelter class i at time t would be in the open at time t, then,

$FE_{it} = FMS_{it} - FP_{it}$

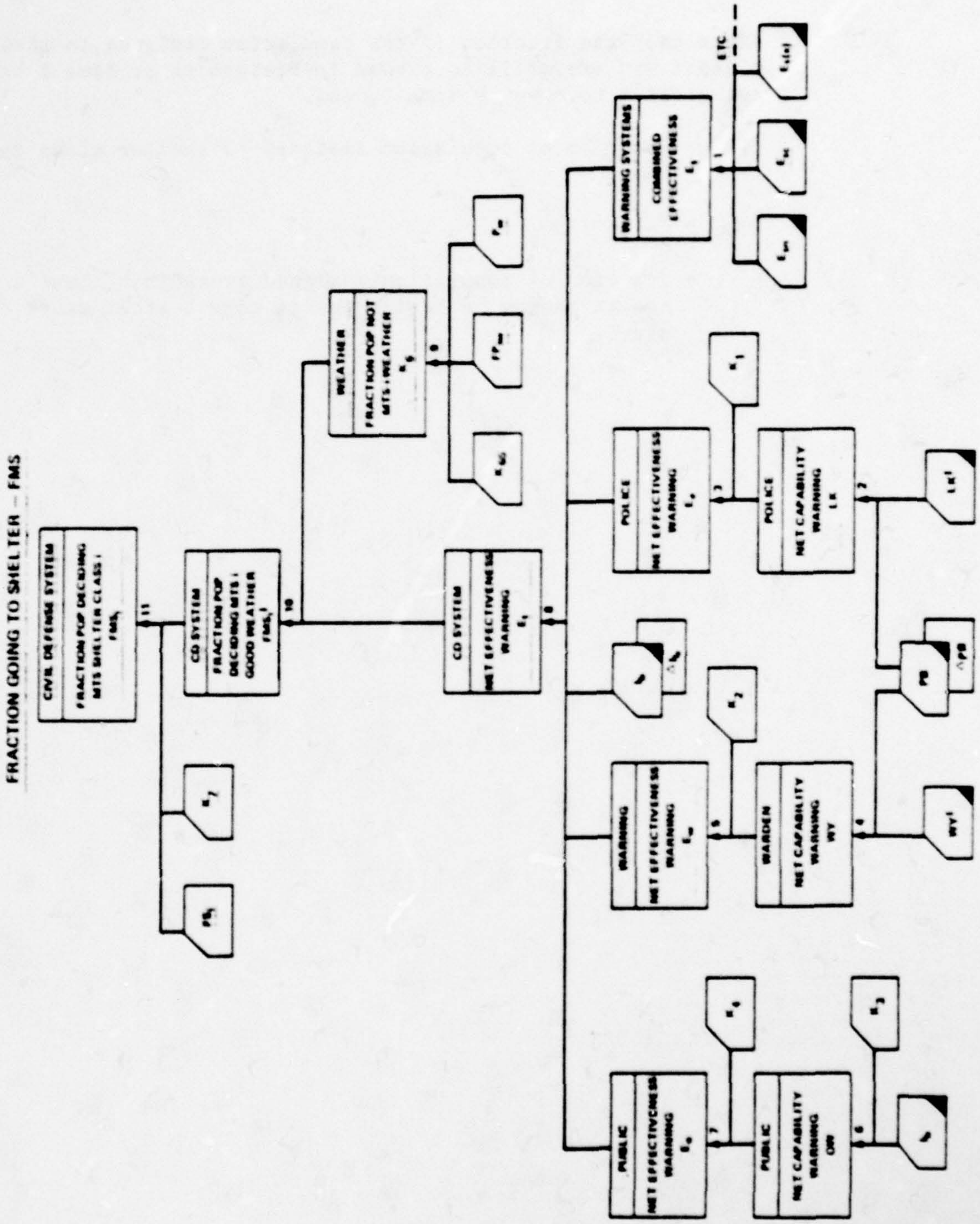
= fraction of population who intend to go to shelter class i who are in open at time t after start of alert.

12. Given that the fraction of the population assigned to shelter class i who are still at random in residences at time t have not started to move by time t, and,

FA_i = fraction of population assigned to shelter class i. Then,

$FS_{it} = FA_i - FMS_{it}$

= fraction of population assigned to shelter class i who are at random in residences at time t after start of alert.


FRACTION GOING TO SHELTER — FMS
CIVIL DEFENSE SYSTEM
CD SYSTEM
WEATHER
NET EFFECTIVENESS WARNING
WARNING SYSTEMS
COMBINED EFFECTIVENESS
POLICE
NET CAPABILITY WARNING
WARNING
WARDEN
PUBLIC
ETC

FRACTION GOING TO SHELTER - FMS_i

Concept

FMS_i = fraction of the total population who would decide to go to shelter class i.

Operation: The public is warned by one or more warning systems and alternatively by public safety (police) and warden services and by members of the public. Adverse weather would deter some people from deciding to go. Some would decide not to go in any event.

Analysis:

1. Given warning systems that are redundant, so that,

E_{sn} = fraction of population warned by NAWAS,

E_{sc} = fraction of population warned by CHAT, and,

$E_{s(x)}$ = fraction of population warned by system (X). Then,

$$E_s = E_{sn} + E_{sc} + E_{s(x)} - E_{sn}E_{sc} - E_{sn}E_{s(x)} - E_{sc}E_{s(x)} + E_{sn}E_{sc}E_{s(x)}$$

= fraction of population warned by all warning systems

2. Given that the public safety services (police) could warn the public if called for in the operations plan,

LK' = fraction of risk population with police service adequate for warning the public,

ΔPB = maximum change in police capability to warn the public between
(a) not having this activity treated in the operations plan, and,
(b) having this activity adequately treated in the operations plan, and,

PB = net adequacy of treatment of police warning activity in operations plan. Then,

$LK = LK'\{1 - \Delta PB(1 - PB)\}$

= fraction of the risk public with police trying to warn them.

3. Given that the police may not be fully effective in warning the public so that,

K_1 = relative capability of police in warning the public. Then,

$E_\ell = K_1 \cdot LK$

= fraction of risk public who can be warned by police.

4. Given that the warden service could warn the public if called for in the operations plan,

WY' = fraction of risk public with warden service adequate for warning the public,

ΔPB = maximum change in warden capability to warn the public between
(a) not having this activity treated in the operations plan, and,
(b) having this activity adequately treated in the operations plan, and

PB = net adequacy of treatment of warden warning activity in operations plan. Then,

$WY = WY'\{1 - \Delta PB(1 - PB)\}$

= fraction of the risk public with warden trying to warn them.

5. Given that the warden service may not be fully effective in warning the public so that,

K_2 = relative capability of warden service in warning the public. Then,

$E_w = K_2 \cdot WY$

= fraction of risk public who can be warned by warden service.

6. Given EPI activities to prepare the public for warning, so that,

I_b = net effectiveness of EPI in preparing the public for warning, and,

K_3 = fraction of the public who would try to assure that others would understand and respond to the warning. Then,

$$OW = K_3 \cdot I_b$$

= fraction of population trying to warn others.

7. Given that members of the public may not be fully effective in warning others so that,

K_4 = relative capability of the public to warn others. Then,

$$E_o = K_4 \cdot OW$$

= fraction of risk public warned by other members of the public.

8. Given
(a) that any member of the public could be warned by any of the four means but need not be warned more than once and
(b) that public reception of the warning could depend on the effectiveness of EPI activities,

ΔI_b = maximum change in fraction of public receiving and understanding the warning between
(a) not having any public preparedness EPI and
(b) having fully effective public preparedness for warning, and,

I_b = net effectiveness of EPI in preparing public for warning. Then,

$$\begin{aligned} E_t = (&E_s + E_\ell + E_w + E_o \\ &- E_sE_\ell - E_sE_w - E_sE_o - E_\ell E_w - E_\ell E_o - E_wE_o \\ &+ E_sE_\ell E_w + E_sE_\ell E_o + E_\ell E_wE_o \\ &- E_sE_\ell E_wE_o)\{1 - \Delta I_b(1 - I_b)\} \end{aligned}$$

= fraction of population who receive and understand the warning.

9. Given that adverse weather may dissuade some people from deciding to go to shelter,

FP_w = fraction of population subject to adverse weather,

P_w = probability of occurrence of adverse weather, and

K_5 = fraction of the population assigned to shelter class i who would decide not to go to shelter because of adverse weather if it occurred. Then,

$$K_6 = K_5 \cdot FP_w \cdot P_w$$

= fraction of population assigned to shelter class i who would decide not to go to shelter because of adverse weather.

10. Given that some fraction of the population would be dissuaded by adverse weather, and,

FA_i = fraction of population assigned to shelter class i. Then,

$$FMS_i' = FA_i \cdot E_t(1 - K_6)$$

= fraction of the population deciding to go to shelter class i if warning is fully effective in persuading them to go.

11. Given that
(a) warning effectiveness could vary among classes of shelter and
(b) some fraction of the population will not go to shelter in any event,

K_7 = relative effectiveness of warning in persuading the population to go to shelter class i, and,

FS_i = fraction of those assigned to shelter class i who will not go. Then,

$$FMS_i = FMS_i'(1 - FS_i)K_7$$

= fraction of total population deciding to go to shelter class i.

EFFECTIVENESS OF WARNING SYSTEMS - $E_{s(x)}$

Concept

$E_{s(x)}$ = net effectiveness of a warning system; i.e., the fraction of the population who would receive, understand, and be persuaded to respond as intended when the warning is given.

Operation: Warning consists of two parts:
(a) an alerting signal to capture the attention of the people and
(b) a message to confirm the reality of the warning and give essential instructions. In some systems the two are combined as in a pure siren system or a pure radio/TV system. In others, they are separate as when the alert is by sirens and the message by radio/TV. The system may be all Federal as when the information goes directly from the National warning center to radio and TV stations. It may be both Federal and local as in NAWAS in which the national warning center passes the information to local warning points and from them to the alerting and informing devices.

Analysis: (System tree overleaf)

1. Given a warning system with Federal informing staff, so that,

DFS' = fraction of the population with adequate trained Federal informing staff,

ΔHI = maximum change in operating capability of Federal informing staff between
(a) not having any organization exercise and
(b) having fully adequate exercises, and

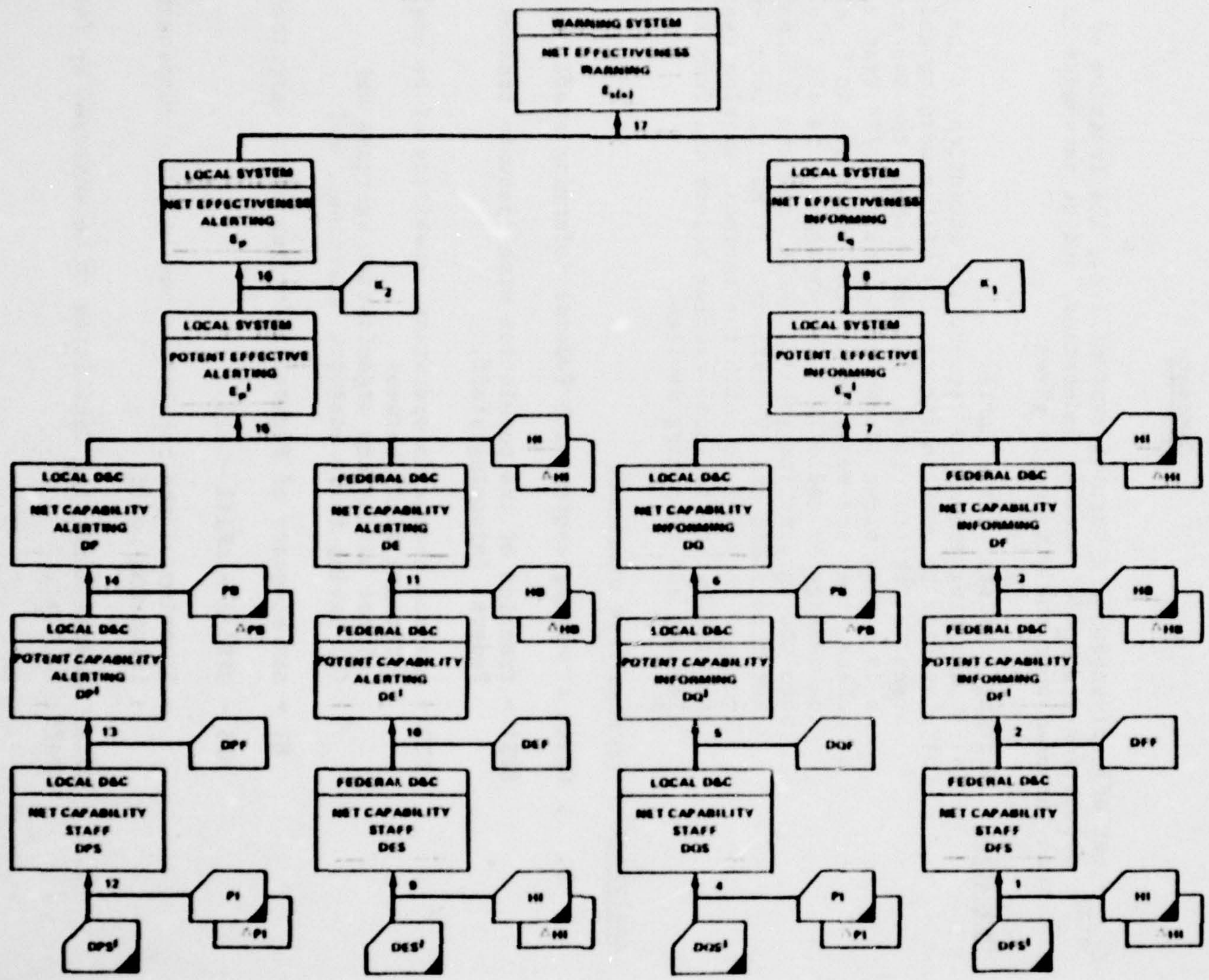
HI = net adequacy of Federal informing staff exercises. Then,

$$DFS = DFS'\{1 - \Delta HI(1 - HI)\}$$

= fraction of the population having fully competent Federal informing staff.

2. Given Federal informing facilities to be employed by informing staff, so that,

EFFECTIVENESS OF WARNING SYSTEMS – $E_{s(x)}$



DFF = fraction of population within range of Federal informing facilities. Then,

$DF' = \text{Min DFS : DFF}$

= fraction of the population who could be informed by the Federal system given adequate operations plans.

3. Given a potential Federal informing capability,

ΔHB = maximum change in informing capability between
(a) not having this activity treated in operations plans and,
(b) having fully adequate treatment in operations plans, and

HB = net adequacy of Federal informing operations plans. Then,

$DF = DF'\{1 - \Delta HB(1 - HB)\}$

= fraction of the population having adequate Federal informing capability.

4. *Given a warning system with local informing staff, so that,*

DQS' = fraction of the population with adequate trained local informing staff,

ΔPI = maximum change in operating capability of local informing staff between
(a) not having any organization exercise and
(b) having fully adequate exercises, and

PI = net adequacy of local informing staff exercises. Then,

$DQS = DQS'\{1 - \Delta PI(1 - PI)\}$

= fraction of the population having fully competent local informing staff.

5. Given local informing facilities to be employed by informing staff so that,

DQF = fraction of population within range of local informing facilities. Then,

$DQ' = DQS \cdot DQF$

= fraction of the population who could be informed by the local system given adequate operations plans.

6. Given a potential local informing capability,

ΔPB = maximum change in informing capability between
(a) not having this activity treated in operations plans, and,
(b) having fully adequate treatment in operations plans, and,

PB = net adequacy of local informing operations plans. Then,

$DQ = DQ'\{1 - \Delta PB(1 - PB)\}$

= fraction of the population having adequate local informing capability.

7. Given a combined Federal/local informing system in which information passes from Federal to local to the public,

ΔHI = maximum change in informing capability of the combined system between
(a) not having any joint organization exercise and
(b) having fully adequate joint exercises, and

HI = net adequacy of joint exercises of Federal and local informing organizations. Then,

$E'_q = (\text{Min } DQ : DF)\{1 - \Delta HI(1 - HI)\}$

= fraction of the population who could be informed if system were fully effective.

8. Given a potential informing capability, and,

K_1 = relative effectiveness of informing system. Then,

$E_q = K_1 \cdot E'_q$

= fraction of the population who can be informed.

9. Given a warning system with Federal alerting staff, so that,

DES' = fraction of the population with adequate trained Federal alerting staff,

ΔHI = maximum change in operating capability of Federal alerting staff between
(a) not having any organization exercise and
(b) having fully adequate exercises, and

HI = net adequacy of Federal alerting staff exercises. Then,

$DES = DES'\{1 - \Delta HI(1 - HI)\}$

= fraction of the population having fully competent Federal alerting staff.

10. Given Federal alerting facilities to be employed by alerting staff so that,

DEF = fraction of population within range of Federal alerting facilities. Then,

$DE' = \text{Min } DES : DEF$

= fraction of the population who could be alerted by the Federal system given adequate operations plans.

11. Given a potential Federal alerting capability,

ΔHB = maximum change in alerting capability between
(a) not having this activity treated in operations plans and,
(b) having fully adequate treatment in operations plans, and,

HB = net adequacy of Federal alerting operations plans. Then,

$DE = DE'\{1 - \Delta HB(1 - HB)\}$

= fraction of the population having adequate Federal alerting capability.

12. Given a warning system with local alerting staff, so that,

DPS' = fraction of the population with adequate trained local alerting staff,

ΔPI = maximum change in operating capability of local alerting staff between
(a) not having any organization exercise and
(b) having fully adequate exercises, and,

PI = net adequacy of local alerting staff exercises. Then,

$$DPS = DPS'\{1 - \Delta PI(1 - PI)\}$$

= fraction of the population having fully competent local alerting staff.

13. Given local alerting facilities to be employed by alerting staff so that,

DPF = fraction of population within range of local alerting facilities. Then,

$$DP' = DPS \cdot DPF$$

= fraction of the population who could be alerted by the local system given adequate operations plans.

14. Given a potential local alerting capability,

ΔPB = maximum change in alerting capability between
(a) not having this activity treated in operations plans and,
(b) having fully adequate treatment in operations plans, and

PB = net adequacy of local alerting operations plans.

$$DP = DP'\{1 - \Delta PB(1 - PB)\}$$

= fraction of the population having adequate local alerting capability.

15. Given a combined Federal/local alerting system in which information passes from Federal to local to the public,

ΔHI = maximum change in informing capability of the combined system between
(a) not having any joint organization exercise and
(b) having fully adequate joint exercises, and

HI = net adequacy of joint exercises of Federal and local alerting organizations. Then,

$$E'_p = (\mathrm{Min\,DP} : \mathrm{DE})\{1 - \Delta HI(1 - HI)\}$$

= fraction of the population who could be alerted if system were fully effective.

16. Given a potential alerting capability, and,

K_2 = relative effectiveness of alerting system. Then,

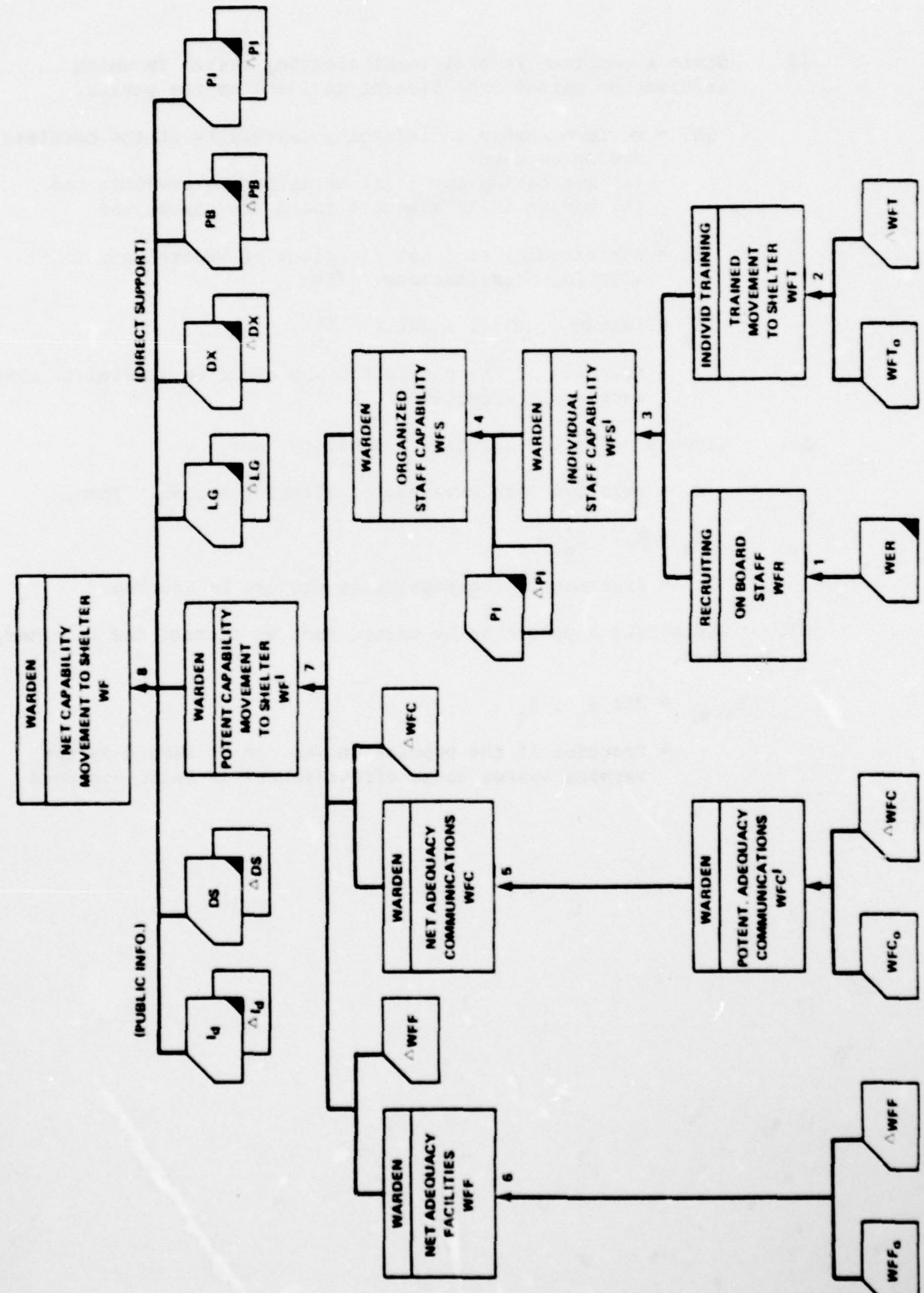
$$E_p = K_2 \cdot E'_p$$

= fraction of the population who can be alerted.

17. Given that a person to be warned must be alerted and informed, then,

$$E_{s(x)} = \mathrm{Min}\ E_p : E_q$$

= fraction of the population who can be warned by the warning system whose effectiveness is being assessed.



WARDEN – MOVEMENT TO SHELTER CAPABILITY – WF

WARDEN-MOVEMENT TO SHELTER CAPABILITY - WF

Concept

WF = net capability of the warden service to manage a movement to shelter.

Operation: People are informed generally of the location of shelters in their vicinity but do not have assignments to specific shelters. Movement to shelter can require less time if guided to avoid bottlenecks. Some shelters will fill before others and people will spend less time in the open if guided to those with available space. The warden service oversees the movement with police support in guidance and maintaining order and D&C information support.

Analysis:

1. Given warden movement staff so that,

   WFR = WER (Page B-23)

   = fraction of population with adequate movement staff at program completion.

2. Given an on-board movement staff that should be trained for movement to shelter,

   WFT_o = fraction of population with adequate trained movement staff at program start, and

   ΔWFT = net additional fraction for whom movement staff is trained in program. Then,

   $WFT = WFT_o + \Delta WFT$

   = fraction of population with adequate trained movement staff at program completion.

3. Given that some of the movement staff may be lost because of staff turnover either before or after being trained, then,

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EFFECTIVENESS OF CIVIL DEFENSE SYSTEMS.(U)
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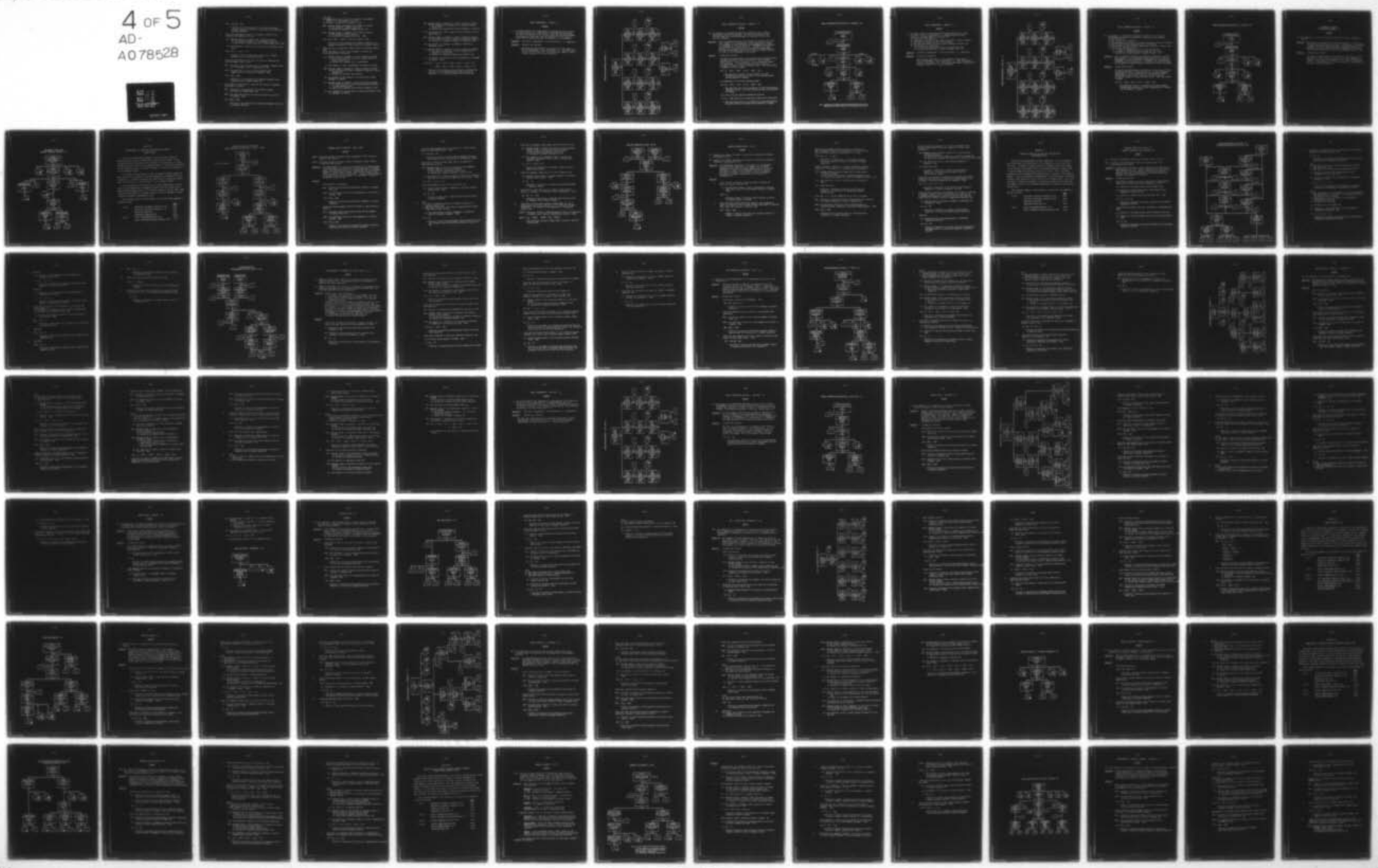

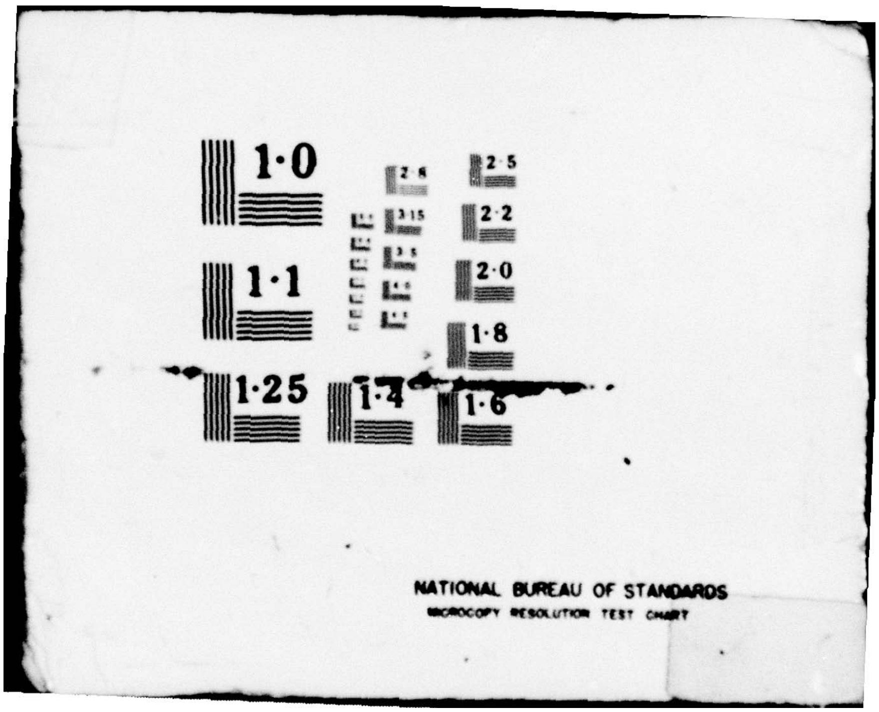
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3·5
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1·1
1·8
1·25
1·4
1·6
NATIONAL BUREAU OF STANDARDS
MICROCOPY RESOLUTION TEST CHART

$WFS' = \text{Min } WFR : WFS$

= fraction of the risk population with adequate movement staff who have had individual training in crisis relocation movement management.

4. Given that organization exercise in emergency operations can increase staff capability so that,

ΔPI = maximum change in movement staff capability between (a) not having any exercise of the movement staff and (b) having fully adequate exercise of the movement staff, and,

PI = net adequacy of exercises for training of the movement staff. Then,

$$WFS = WFS'\{1 - \Delta PI(1 - PI)\}$$

= fraction of the risk population having fully competent movement staff at program completion.

5. Given that the warden service could have service communications for the movement staff so that,

WFC_o = fraction of the risk population with adequate communications for the movement staff at program start, and

ΔWFC = net additional fraction for whom movement staff communications are procured in program. Then,

$$WFC = WFC_o + \Delta WFC$$

= fraction of risk population with adequate movement staff communications at program completion.

6. Given that the warden service could have facilities for managing the movement to shelter.

WFF_o = fraction of risk population with adequate movement facilities at program start, and

ΔWFF = net additional fraction for whom facilities are procured in program. Then,

$$WFF = WFF_o + \Delta WFF$$

= fraction of risk population with adequate movement facilities at program completion.

7. Given that
(a) communications and facilities can enhance the management capability of the movement staff and
(b) it would be limited by the lesser of them.

ΔWFC = maximum change in movement staff capability between
(a) not having any communications and
(b) having fully adequate communications, and,

ΔWFF = maximum change in movement staff capability between
(a) not having any facilities and
(b) having fully adequate facilities. Then,

$$WF' = WFS \cdot \mathrm{Min}\{1 - \Delta WFC(1 - WFC)\}:\{1 - \Delta WFF(1 - WFF)\}$$

= fraction of risk population with adequate capability to manage the movement to shelter given the necessary support.

8. Given that the CD organization should support the warden movement staff
(a) by informing the public about movement to shelter and
(b) by giving direct assistance,

ΔI_d = maximum change in movement to shelter capability between
(a) not having any EPI activities to prepare people for going to shelter and
(b) having fully adequate public preparedness.

I_d = net adequacy of public preparedness for going to shelter.

ΔDS = maximum change in movement to shelter capability between
(a) not having any D&C public information capability during movement and
(b) having fully adequate D&C capability

DS = net adequacy of D&C capability to inform public during movement to shelter,

ΔLG = maximum change in movement to shelter capability between
(a) not having any police service guidance and maintenance of order capability and
(b) having fully adequate police service capability, and,

LG = net capability of police service to guide and maintain order in a movement to shelter,

ΔDX = maximum change in movement to shelter capability between
(a) not having any D&C capability to inform the warden service and
(b) having fully adequate D&C system information capability,

DX = net capability of D&C to supply system information to the warden service,

ΔPB = maximum change in movement to shelter capability between
(a) not having the activity treated in operations plans and
(b) having fully adequate treatment in operations plans,

PB = net adequacy of treatment of movement to shelter in operations plans,

ΔPI = maximum change in movement to shelter capability between
(a) not having any exercise of the CD organization in movement to shelter and
(b) having fully adequate organization exercise, and

PI = net adequacy of exercise of the CD organization in movement to shelter. Then,

$$WF = WF'\{1 - \Delta I_d(1 - I_d)\}\{1 - \Delta DS(1 - DS)\}\{1 - \Delta LG(1 - LG)\}$$
$$\{1 - \Delta DX(1 - DX)\}\{1 - \Delta PB(1 - PB)\}\{1 - \Delta PI(1 - PI)\}$$

= fraction of the population who are moving to shelter who can arrive in the shelters within time t_m given the capability of the warden movement staff as supported.

PUBLIC PREPAREDNESS - WARNING - I_b

Concept

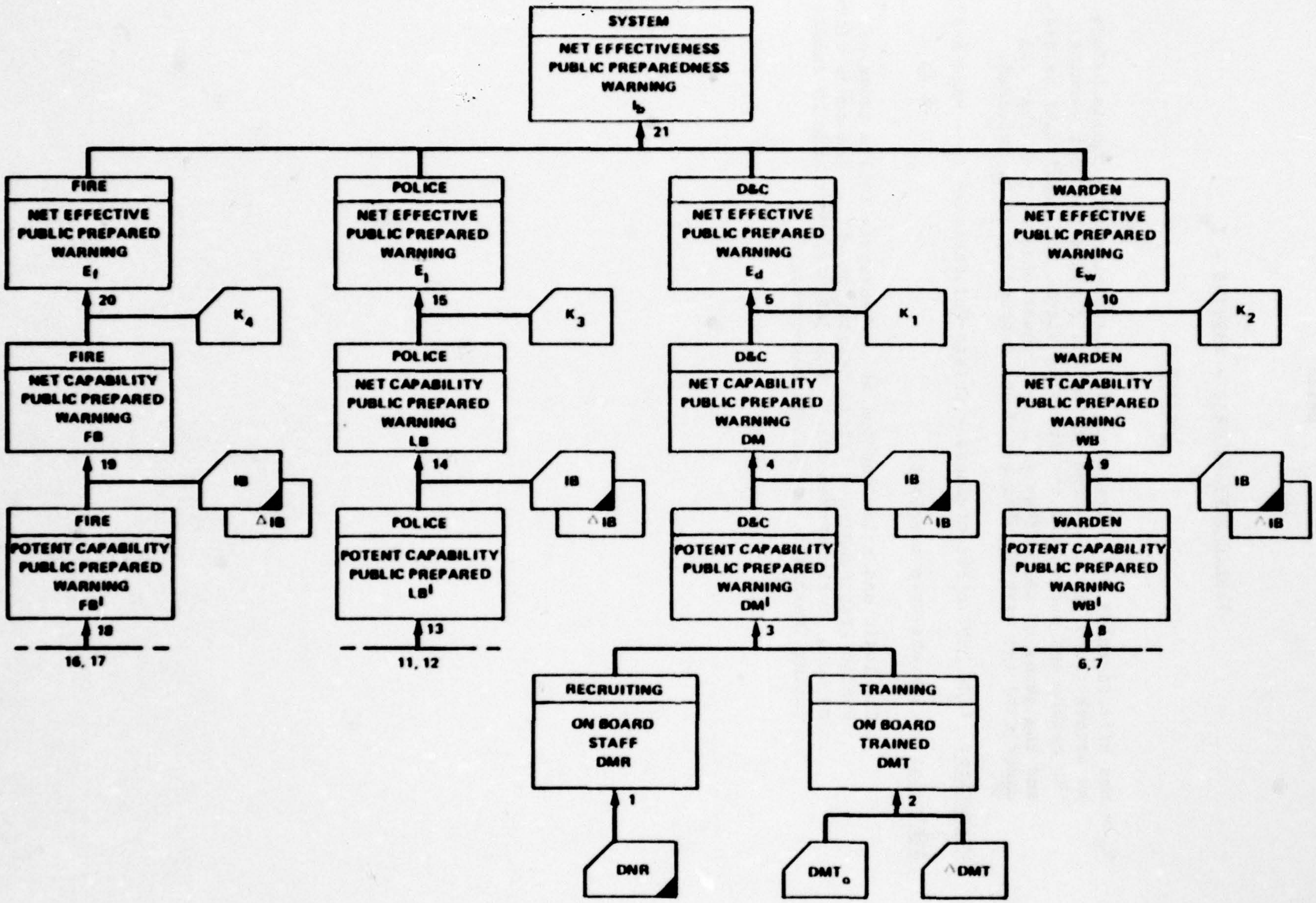
I_b = net effectiveness of CD organization in educating the public before an attack (such as in a surge period) to prepare them for warning: the nature and meaning of the alerting signal and confirming message, and the means by which they will be transmitted, so that they can understand the warning when given and respond to it as intended.

Operation: (See Public Preparedness - Crisis Relocation - I_c - Page B-83)

Analysis: (Systems tree overleaf)

The logic and relationships of the analysis follow those of Public Preparedness - Crisis Relocation - I_c. The codes differ as seen in the system tree. The definitions change by substituting "warning" for "crisis relocation."

PUBLIC PREPAREDNESS–WARNING – I_b



PUBLIC INFORMATION MATERIALS - WARNING - IB

Concept

IB = net adequacy of informational materials prepared for use in public preparedness education in warning: the nature and meaning of the alerting signal and confirming message and the means by which they will be transmitted.

Operation: Public information materials are prepared by personnel of an EPI staff element of the preparedness system organization trained for assignment to their positions and arrangements are concluded for dissemination of these materials. Information for these materials can be supplied from the planning and development of alerting and informing capabilities of warning systems, national, or local, or both depending on the program.

Analysis: (System tree overleaf)

The logic and relationships of the analysis follow those of Public Information Materials-Crisis Relocation-IC, with "warning" substituted for "crisis relocation" in the definitions, except in relationship 5, in which warning plans are sources of information instead of crisis relocation plans. Then relationship 5 becomes, for local systems,

$$\Delta IB = K_1 \cdot IBS\{1 - \Delta AD(1 - AD)\}\{1 - \Delta AE(1 - AE)\}$$

= net additional fraction of the population for whom informational materials related to local warning systems can be prepared in program.

or alternatively for national warning systems,

$$\Delta IB = K_1 \cdot IBS\{1 - \Delta AA(1 - AA)\}\{1 - \Delta AB(1 - AB)\}$$

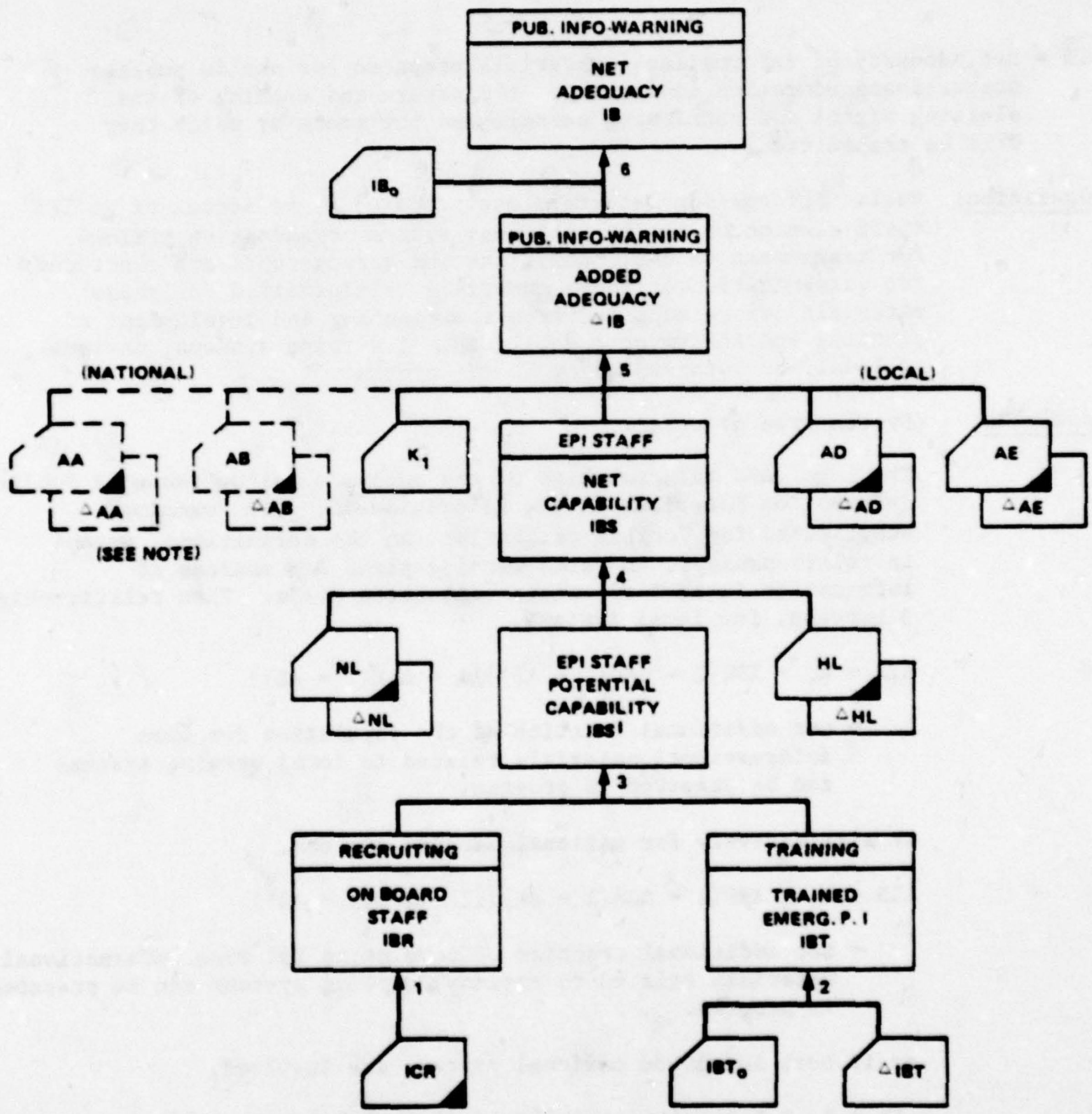
= net additional fraction of population for whom informational materials related to national warning systems can be prepared in program.

or if both local and national systems are involved,

$$IB = K_1 \cdot IBS\{1-\Delta AA(1-AA)\}\{1-\Delta AB(1-AB)\}\{1-\Delta AD(1-AD)\}\{1-\Delta AE(1-AE)\}$$

= net additional fraction of population for whom informational materials related to warning can be prepared in program.

PUBLIC INFORMATION MATERIALS – WARNING – IB



NOTE: DEPENDING ON PROGRAM, PUBLIC PREPAREDNESS INFORMATION MAY BE NEEDED FOR A NATIONAL WARNING, A LOCAL WARNING SYSTEM, OR BOTH.

PUBLIC PREPAREDNESS - SHELTER - I_d

Concept

I_d = net effectiveness of CD organization in educating the public before an attack -- as in a surge period -- to prepare them for going to shelter by informing them of such matters as:

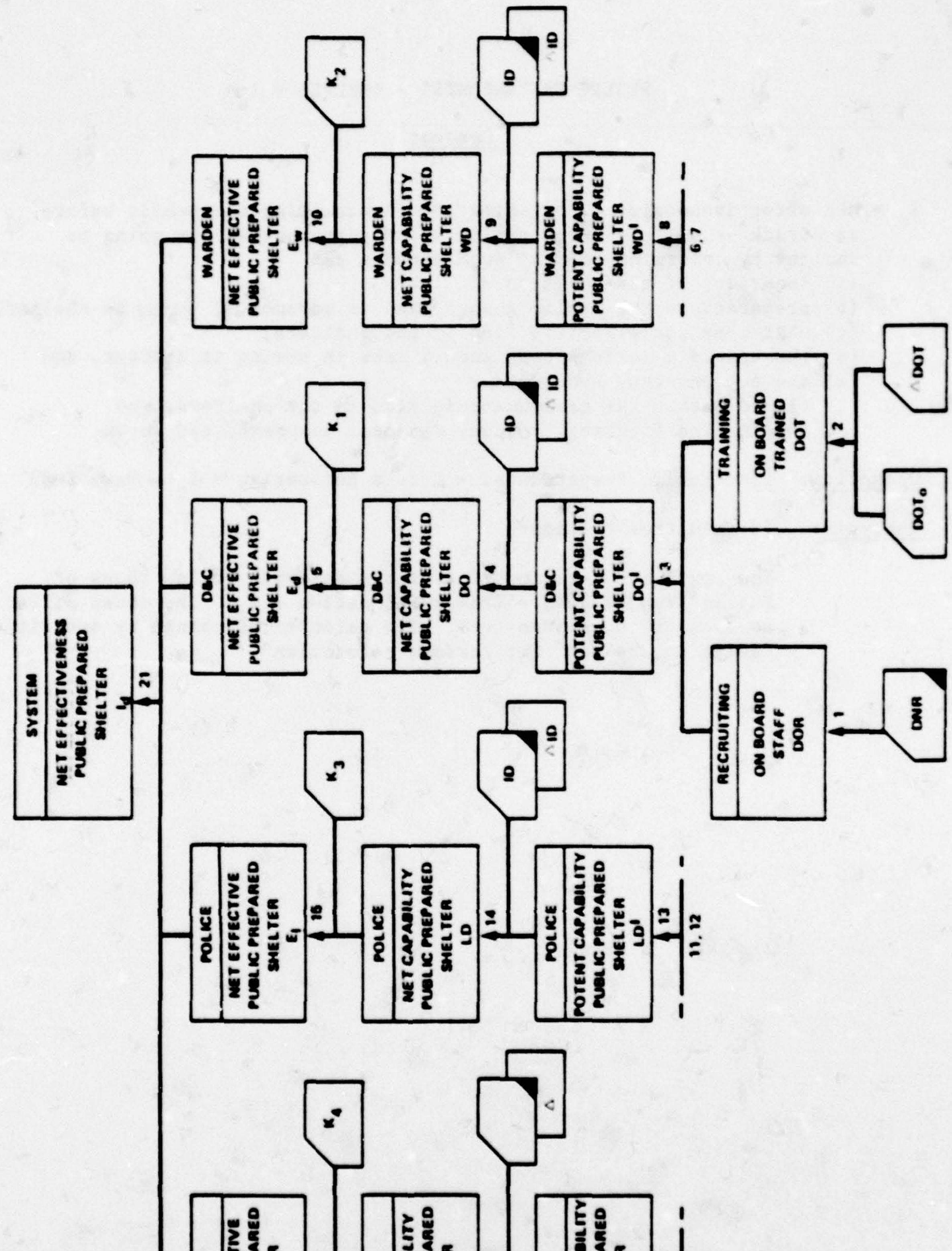
(a) locations of the shelters,
(b) preparations the public should make in advance of going to shelter,
(c) what they can expect to find in the shelters,
(d) the specific actions they should take in moving to shelter, and
(e) the actions they should take
  (1) to obtain the maximum protection in the shelters, and
  (2) in fire fighting, rescue, remedial movement, and so on.

Operation: (See Public Preparedness - Crisis Relocation - I_c - Page B-83)

Analysis: (System tree overleaf)

The logic and relationships of the analysis follow those of Public Preparedness - Crisis Relocation - I_c. The codes differ as seen in the system tree. The definitions change by substituting "going to shelter" for "crisis relocation".

PUBLIC PREPAREDNESS – SHELTER – I_d



PUBLIC INFORMATION MATERIALS - SHELTER - ID

Concept

ID = net adequacy of informational materials prepared for use in public preparedness education for occupation of the shelters and addressed to such subjects as
(a) the location of the shelters,
(b) the preparations the public should make in advance of going to shelter,
(c) what the public should expect to find in the shelter,
(d) the specific actions the people should take in moving to shelter, and
(e) the actions they should take
  (1) to obtain the maximum protection in the shelter and
  (2) in regard to measuring radiation, fighting fire, rescue, ventilation, conserving water, remedial movement, etc.

<u>Operation</u>: Public information materials are prepared by personnel of an EPI staff element of the preparedness system organization trained for assignment to their positions and arrangements are concluded for dissemination of these materials. Information for these materials can be supplied by Federal and State CD and from shelter use plans.

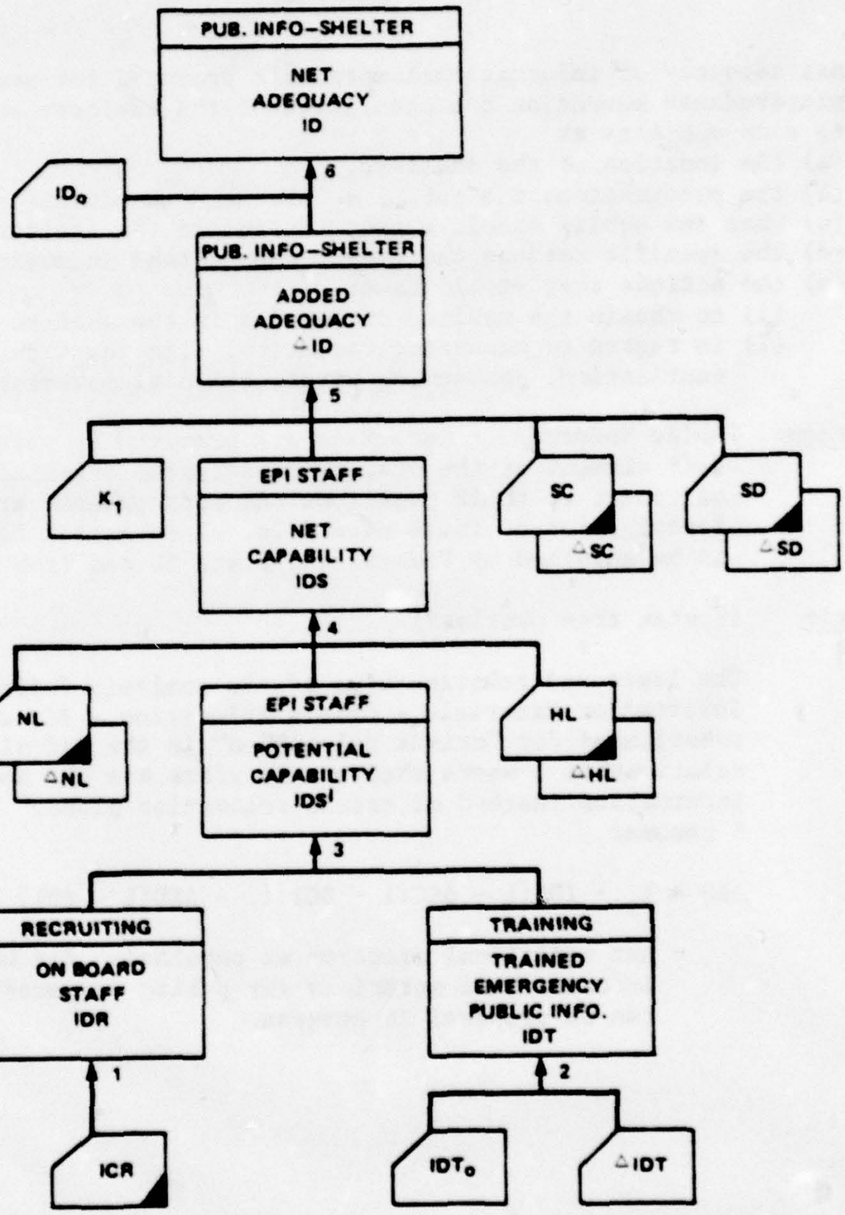
<u>Analysis</u>: *(System tree overleaf)*

The logic and relationships of the analysis follow those of Public Information Materials - Crisis Relocation - IC, with "shelter" substituted for "crisis relocation" in the definition except in relationship 5 where shelter use plans are the sources of information instead of crisis relocation plans. Then relationship 5 becomes,

$$\Delta ID = K_1 \cdot IDS\{1 - \Delta SC(1 - SC)\}\{1 - \Delta SD(1 - SD)\}$$

= net additional fraction of population for whom adequate informational materials for public preparedness for shelters can be prepared in program.

PUBLIC INFORMATION MATERIALS – SHELTER – ID



MOVEMENT TO SHELTER
POLICE-CONTROL TRAFFIC - LG

Concept

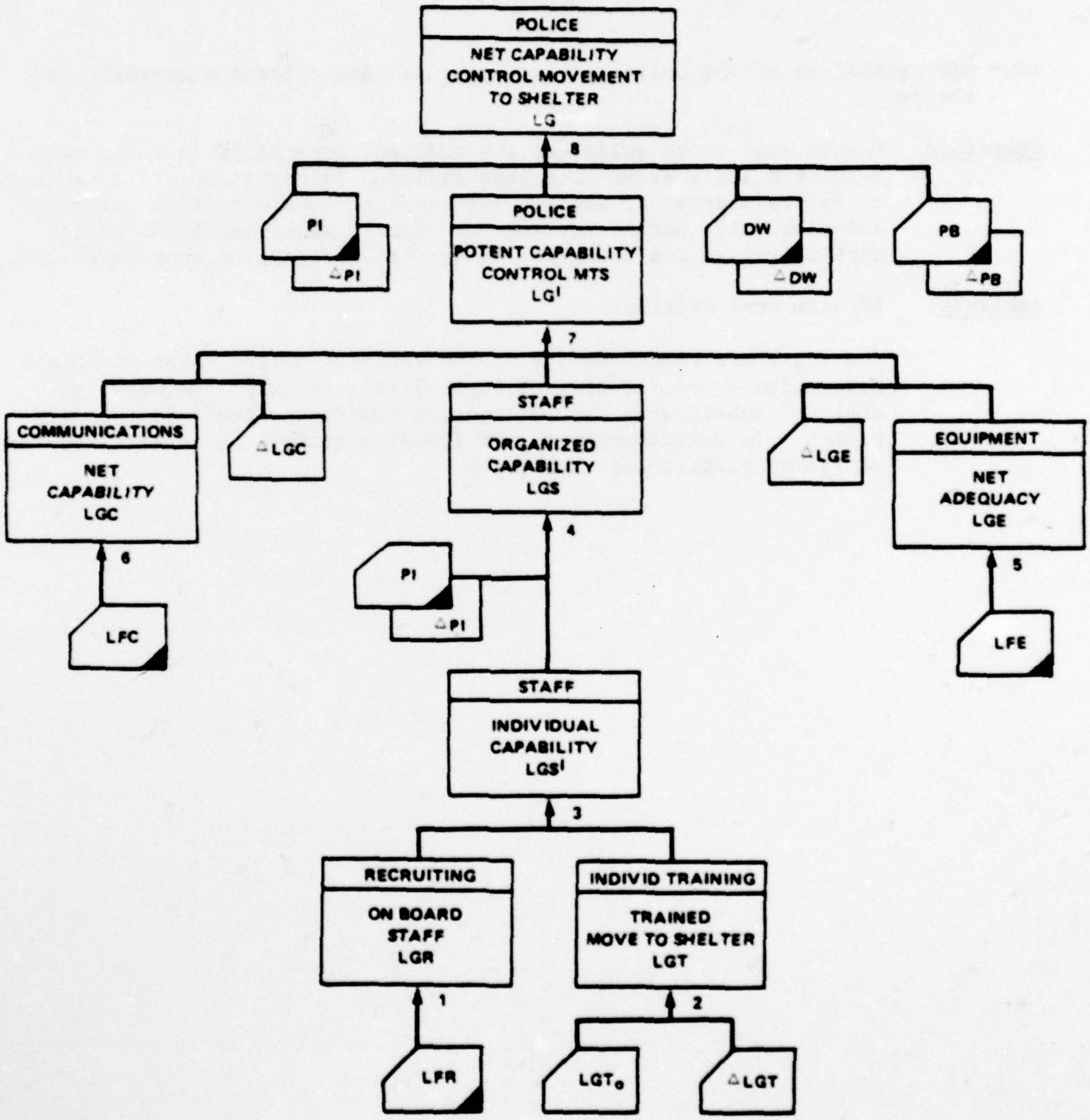
LG = net capability of the police service to guide and control a movement to shelter.

Operation: People need to be guided to the shelters especially to those with available space after some have filled. In addition, it is necessary to maintain order at shelter entrances to assure minimum delay in entering. The warden service has overall management; the police service guides and maintains order with information support by D&C.

Analysis: (System tree overleaf)

The logic and relationships of the analysis follow those of Crisis Relocation - Traffic Control Capability - LF, with "movement to shelter" substituted for "relocation traffic control" in the definition. In relationship 8, PI (local exercise) is substituted for NI (joint State/local exercise).

MOVEMENT TO SHELTER
POLICE – CONTROL TRAFFIC – LG



SECTION B.3

EFFECTIVENESS IN IMPROVING BLAST PROTECTIVE POSTURE (ΔMLOP, ΔMCOP)

This part of PAM produces estimates of the fractional increase in median lethal and casualty overpressures achieved by the system. In use the model produces an estimate of the fraction of the population of a given shelter class that would be in the improved posture. This fraction is applied to the potential increase (a technical estimate) to arrive at an estimate of the net average increase.

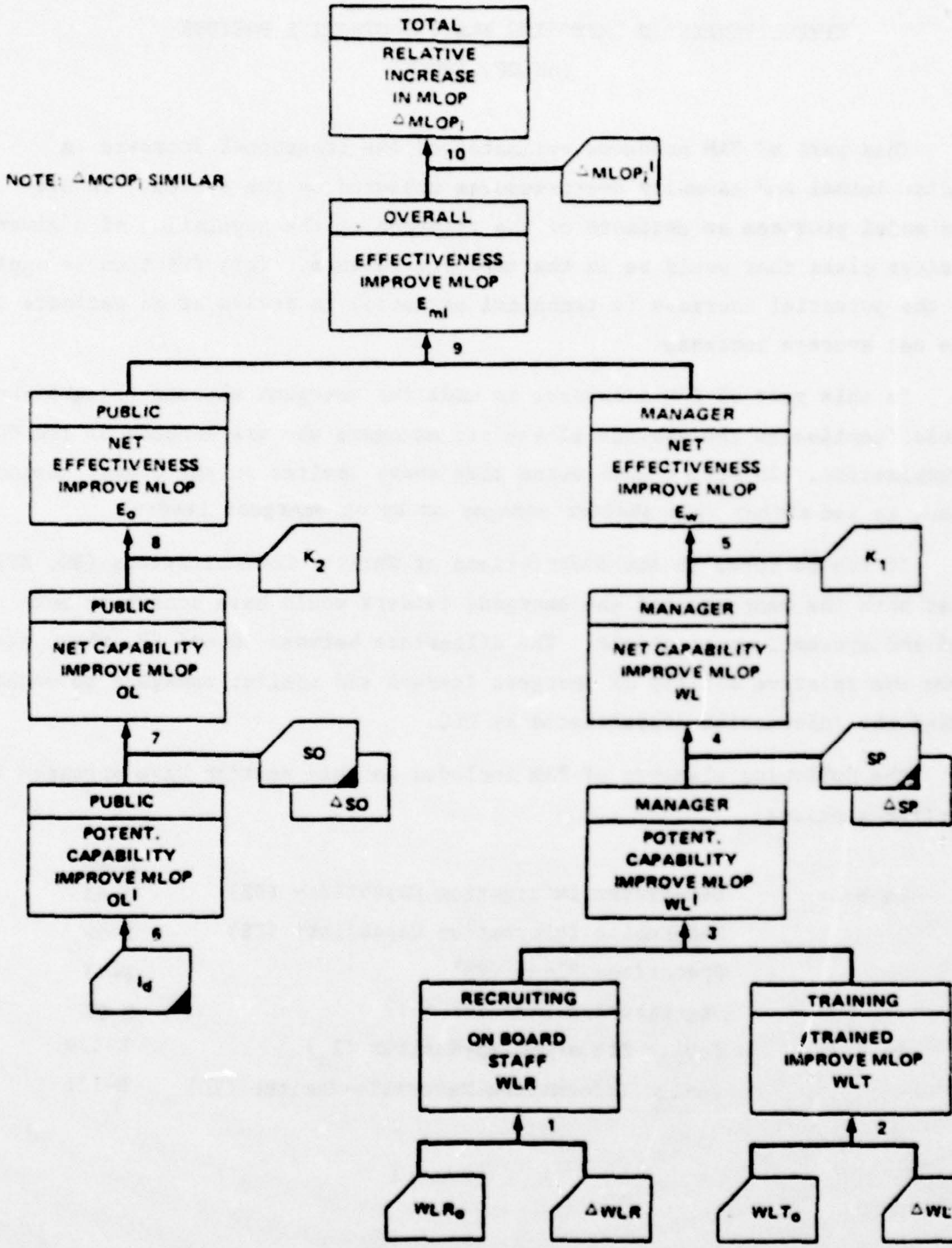
In this part of PAM allowance is made for emergent shelter leaders who would function in the absence of shelter managers who are members of the CD organization. In effect this means that every shelter in the class, nation-wide, is led either by a shelter manager or by an emergent leader.

It can be noted in the descriptions of Shelter Communications (SO, SP) that both the managers and the emergent leaders would have access to both EBS and system communications. The difference between SO and SP, then, stems from the relative ability of emergent leaders and shelter managers to understand the information disseminated by D&C.

The following elements of PAM included in this section have appeared in earlier sections:

		Page
In B.1:	D&C-System Information Capability (DZ)	B-63
	D&C-Public Information Capability (DS)	B-69
	Operations Plans (PB)	B-75
	Organization Exercise (PI)	B-97
In B.2:	Public Preparedness-Shelter (I_d)	B-129
	Public Information Materials-Shelter (ID)	B-131

EFFECTIVENESS IN IMPROVING
BLAST PROTECTIVE POSTURE – (Δ MLOP, Δ MCOP)



INCREASED BLAST PROTECTION - ΔMLOP, ΔMCOP

Concept

ΔMLOP = fractional increase in median lethal overpressure (MLOP) because of improved blast posture.

ΔMCOP = fractional increase in median casualty overpressure (MCOP) because of improved blast posture.

Operation: The effectiveness of a shelter in protecting its occupants against injury and death from blast effects can be increased by arranging them in the preferred posture (e.g., seated near walls and columns) instead of leaving them at random. Shelter blast ratings ($MLOP_i$, $MCOP_i$) are based on random distribution. Improved blast posture can be achieved by the shelter manager or by an emergent leader with information support by D&C.

Analysis:

1. Given shelters with managers,

   WLR_o = fraction of population having shelter managers at program start, and

   ΔWLR = net additional fraction for whom managers are recruited in program. Then,

   $WLR = WLR_o + \Delta WLR$

   = fraction of population having shelter managers at program completion.

2. Given that shelter managers should be trained in improving blast posture,

   WLT_o = fraction of population having trained shelter managers at program start, and

   ΔWLT = net additional fraction for whom managers are trained in program. Then,

   $WLT = WLT_o + \Delta WLT$

   = fraction of population having shelter managers trained in improved blast posture at program completion.

3. Given that some managers may be lost because of turnover either before or after being trained. Then,

$$WL' = \text{Min } WLR : WLT$$

= fraction of population having shelter managers who would try to improve blast posture given D&C information support.

4. Given that the shelter manager might need to be reminded of improving blast posture,

ΔSP = maximum change in fraction of population with managers trying to improve blast posture between
(a) not having any information from D&C and
(b) having fully adequate information from D&C, and

SP = net capability of shelter managers to receive and understand instructions from D&C about improving blast posture. Then,

$$WL = WL'\{1 - \Delta SP(1 - SP)\}$$

5. Given that managers may not be fully effective, and

K_1 = relative effectiveness of managers in achieving improved blast posture. Then,

$$E_w = K_1 \cdot WL$$

= fraction of population in improved blast posture because of shelter managers.

6. Given
(a) a public information activity to prepare the public for shelter occupancy and
(b) that some of the public will learn of improved blast posture from this activity, so that,

I_d = net effectiveness of public information in preparing public for shelter occupancy. Then,

$$OL' = I_d$$

= fraction of public having emergent shelter leaders who would try to improve blast posture given information support by D&C.

7. Given that the emergent leader might need instructions by D&C,

ΔSO = maximum change in fraction of population having emergent leaders trying to improve blast posture between (a) not having any information from D&C and, (b) having fully adequate information, and

SO = net capability of an emergent leader to receive and understand information from D&C about improving blast posture. Then,

$$OL = OL'\{1 - \Delta SO(1 - SO)\}$$

= fraction of population with emergent leaders trying to improve blast posture.

8. Given that emergent leaders may not be fully effective, and

K_2 = relative effectiveness of emergent leaders in achieving improved blast posture. Then,

$$E_o = K_2 \quad OL$$

= fraction of population in improved blast posture because of emergent leaders.

9. Given that any individual may be in improved blast posture because of a manager or an emergent leader independently. Then,

$$E_{ml} = E_w + E_o - E_w E_o$$

= fraction of population in improved blast posture because of managers and/or emergent leaders.

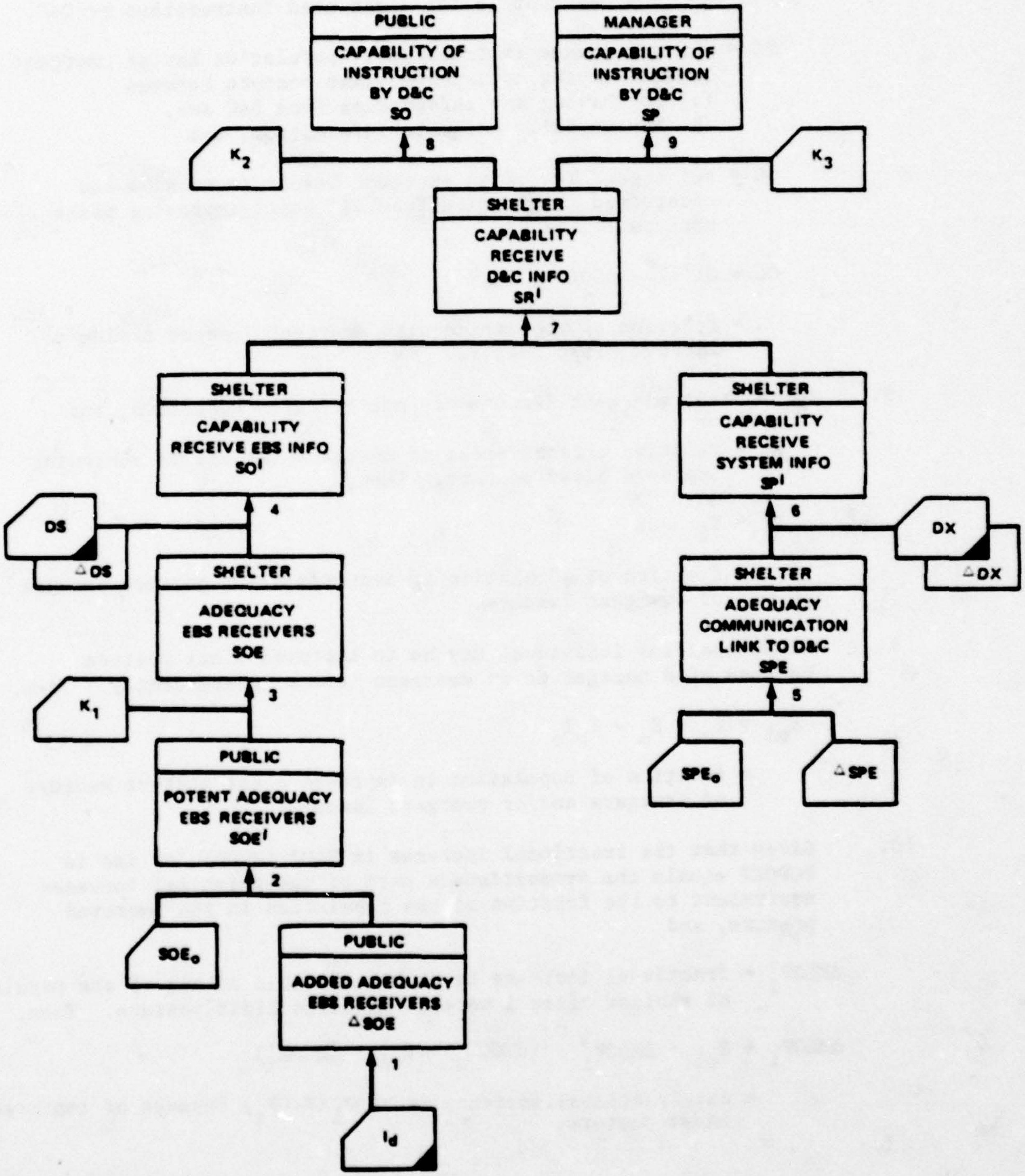
10. Given that the fractional increase in MLOP (MCOP) for use in POPDEF equals the proportionate part of the potential increase equivalent to the fraction of the population in the improved posture, and

$\Delta MLOP'_i$ = fractional increase in MLOP achievable if all of the population of shelter class i were in improved blast posture. Then,

$$\Delta MLOP_i = E_{ml} \cdot \Delta MLOP'_i \quad (\Delta MCOP_i = E_{ml} \cdot \Delta MCOP'_i)$$

= net fractional increase in $MLOP_i$ ($MCOP_i$) because of improved blast posture.

SHELTER COMMUNICATIONS – SO, SP



SHELTER COMMUNICATIONS - SO, SP

Concept

SO = Capability of shelter occupants to receive and understand information disseminated by D&C.

SP = Capability of shelter organization personnel to receive and understand information disseminated by D&C.

Operation: D&C disseminates information to the public via the emergency broadcast system (EBS) and to the elements of the system organization via whatever system communications are provided. The public is urged to take broadcast receivers to shelter. The ability of those in the shelters to receive information from D&C is increased in proportion to D&C's ability to disseminate it.

Analysis:

1. Given a public information program intended to prepare the public for going to shelter, and

I_d = the net effectiveness of public information in inducing additional people to take broadcast receivers to shelter. Then,

$\Delta SOE = I_d$

= additional number of families taking broadcast receivers to shelter because of program.

2. Given that some families have been induced by past programs so that, at the start of the projected program, some number of families, SOE_o, would take receivers to shelter, then

$SOE' = SOE_o + \Delta SOE$

= number of families who would take broadcast receivers to shelter at program completion.

3. Given that the average shelter would have K_1 families and that the maximum fraction of the population of a shelter class that could have receivers in the shelter = 1.0, then,

$$SOE = \text{Min } 1.0: \; K_1 \cdot SOE'$$

= fraction of the population of the shelter class who would have broadcast receivers in shelter at program completion.

4. Given an in-shelter capability to receive information broadcast via EBS and a D&C capability to broadcast public information,

ΔDS = maximum change in shelter capability to receive public information between
(a) not having any D&C public information capability and
(b) having fully adequate D&C public information capability, and

DS = net capability of D&C to broadcast public information. Then,

$$SO' = SOE\{1-\Delta DS(1-DS)\}$$

= fraction of population of shelter class having the capability to receive public information broadcast by D&C via EBS.

5. Given some, or no, system communications at start of program,

SPE_o = fraction of population having in-shelter means for receiving D&C system information at start of program, and

ΔSPE = net additional fraction for whom in-shelter means for receiving system information are procured during program. Then,

$$SPE = SPE_o + \Delta SPE$$

= fraction having in-shelter means for receiving system information at program completion.

6. Given the in-shelter capability to receive information from D&C over system channels and a D&C capability to send system information,

ΔDX = maximum change in shelter capability to receive system information between
(a) not having any D&C capability to inform the system and
(b) having fully adequate D&C capability to inform the system, and

DX = net capability of D&C to send system information to shelters. Then,

$$SP' = SPE\{1-\Delta DX(1-DX)\}$$

= fraction of population of shelter class having the capability to receive system information sent by D&C via system channels.

7. Given that both occupants and organization personnel can receive information from D&C both via EBS and via system channels, the two means of receiving information are redundant. Then,

$$SR' = SO' + SP' - SO' \cdot SP'$$

= fraction of population of the shelter class having the capability to receive information from D&C.

8. Given that the occupants of the shelters in the class -- including an emergent leader -- have a relative ability, less than 1.0, to understand information received from D&C and that this may differ from the relative ability of organization personnel, and

K_2 = relative ability of shelter occupants to understand D&C information. Then,

$$SO = K_2 \cdot SR'$$

= fraction of population of shelter class having the capability to receive and understand D&C information.

9. Similarly,

K_3 = relative ability of system personnel to understand information from D&C.

$$SP = K_3 \cdot SR'$$

= fraction of population of shelter class with organization personnel ability to receive and understand information from D&C.

SECTION B.4

FRACTIONS FORCED OUT BY FIRE (FF) AND SURVIVING FIRE EFFECTS (FFS)

This part of PAM represents two major operations: (a) fire prevention which occurs before the attack and (b) fire suppression which occurs after the attack. In essence the model produces an estimate of the effectiveness of fire prevention and applies this to the potential number of initial fires to find the number of buildings initially set on fire. Then it produces estimates of fire suppression effectiveness which it applies to the estimated number of fires in succeeding fire generations to find the number of buildings burning in each generation and the total for all the generations. Then, from the total it produces an estimate of the Fraction Forced Out (FF) and, from the number of fires in the individual generations, the Fraction Surviving Fire Effects (FFS).

The following elements of PAM included in this section have appeared in earlier sections:

FRACTION FORCED OUT BY FIRE (FF)
FRACTION FORCED OUT AND SURVIVING (FFS)

Concept

FF_i = fraction of population forced out of shelter class i by fire.

FFS_i = fraction of the population forced out of shelter class i and surviving the fire effects.

Operation: Burning of the structures in which shelters are located forces their occupants to leave. Some of those forced out die from the fire effects. Fires can spread to structures not initially ignited. Fires can be extinguished by both shelter-based and organized fire suppression activites.

Analysis: (System tree overleaf)

1. Given initial primary fires and a possibility of extinguishing them both by the blast wave and by suppression actions,

   a_o = fraction of buildings having initial primary fires,

   e_a = fraction of initial primary fires extinguished by fire suppression activities, and,

   c_o = fraction of primary fires surviving blast wave. Then,

   $f_a = a_o \cdot c_o(1 - e_a)$

   = fraction of buildings with initial primary fires surviving suppression efforts.

2. Given initial secondary fires and a possibility of extinguishing them,

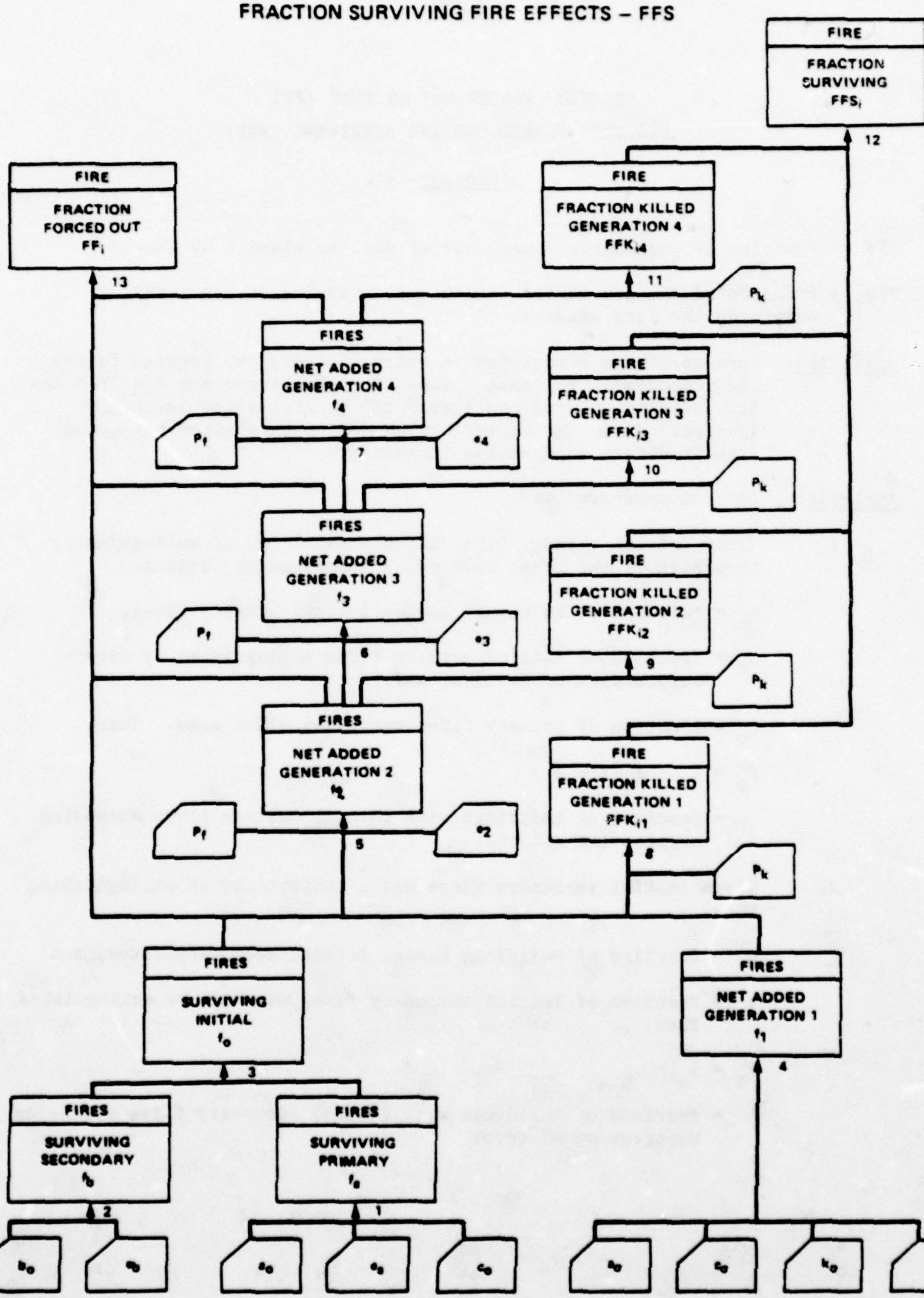
   b_o = fraction of buildings having initial secondary fires, and

   e_b = fraction of initial secondary fires that can be extinguished. Then,

   $f_b = b_o \cdot e_b$

   = fraction of buildings with initial secondary fires surviving suppression efforts.

FRACTION FORCED OUT BY FIRE – FF
FRACTION SURVIVING FIRE EFFECTS – FFS



3. Given that a building may be on fire because of either primary ignition or secondary ignition, then,

$$f_o = f_b + f_a$$

= fraction of buildings with sustained fires after the blast wave and initial suppression activities.

4. Given
(a) that some of the primary fires extinguished by the blast wave can rekindle and
(b) that these may be extinguished by suppression actions,

K_o = fraction of primary fires rekindling after being extinguished by blast wave, and

e_1 = fraction of rekindled fires extinguished by suppression activities. Then,

$$f_1 = a_o(1 - c_o)\, K_o\, (1 - e_1)$$

= fraction of buildings with first generation (rekindled) fires after first-generation suppression activities.

5. Given
(a) that the number of fires generated by fire spread depends on the number burning at the start of the generation and the rate (probability) of spread,
(b) that these new fires can possibly be extinguished by suppression actions, and,
(c) for the second generation,

p_f = probability of fire spread, and

e_2 = fraction of second generation fires extinguished by suppression activities. Then,

$$f_2 = f_o + f_1 \cdot p_f(1 - e_2)$$

= fraction of buildings with sustained fires after second-generation suppression activities.

6. Similarly,

e_3 = fraction of third generation fires extinguished by suppression activities.

$f_3 = f_2 \cdot p_f(1 - e_3)$

= fraction of buildings with sustained fires after third-generation suppression activities.

7. Similarly,

e_4 = fraction of fourth generation fires extinguished by suppression activities.

$f_4 = f_3 \cdot p_f(1 - e_4)$

= fraction of buildings with sustained fires after fourth-generation suppression activities.

8. Given that the fraction of those forced out by fire who are killed depends on
(a) the number of buildings on fire in the fire generation and
(b) the rate at which they are killed, and

P_k = rate at which people forced out by fire are killed by fire effects. Then,

$FFK_{i1} = p_k \cdot f_1$

= fraction of those forced out of shelter class i killed in fire generation one.

9. Similarly,

$FFK_{i2} = p_k \cdot f_2$

= fraction of population of shelter class i killed in fire generation two.

10. Similarly,

$FFK_{i3} = p_k \cdot f_3$

= fraction of population of shelter class i killed in fire generation three.

11. $FFK_{i4} = p_k \cdot f_4$

= fraction of population of shelter class i killed in fire generation four.

12. Given that those surviving are those not killed,

$$FFS_i = 1 - \sum_{0}^{4} FFK_{in}$$

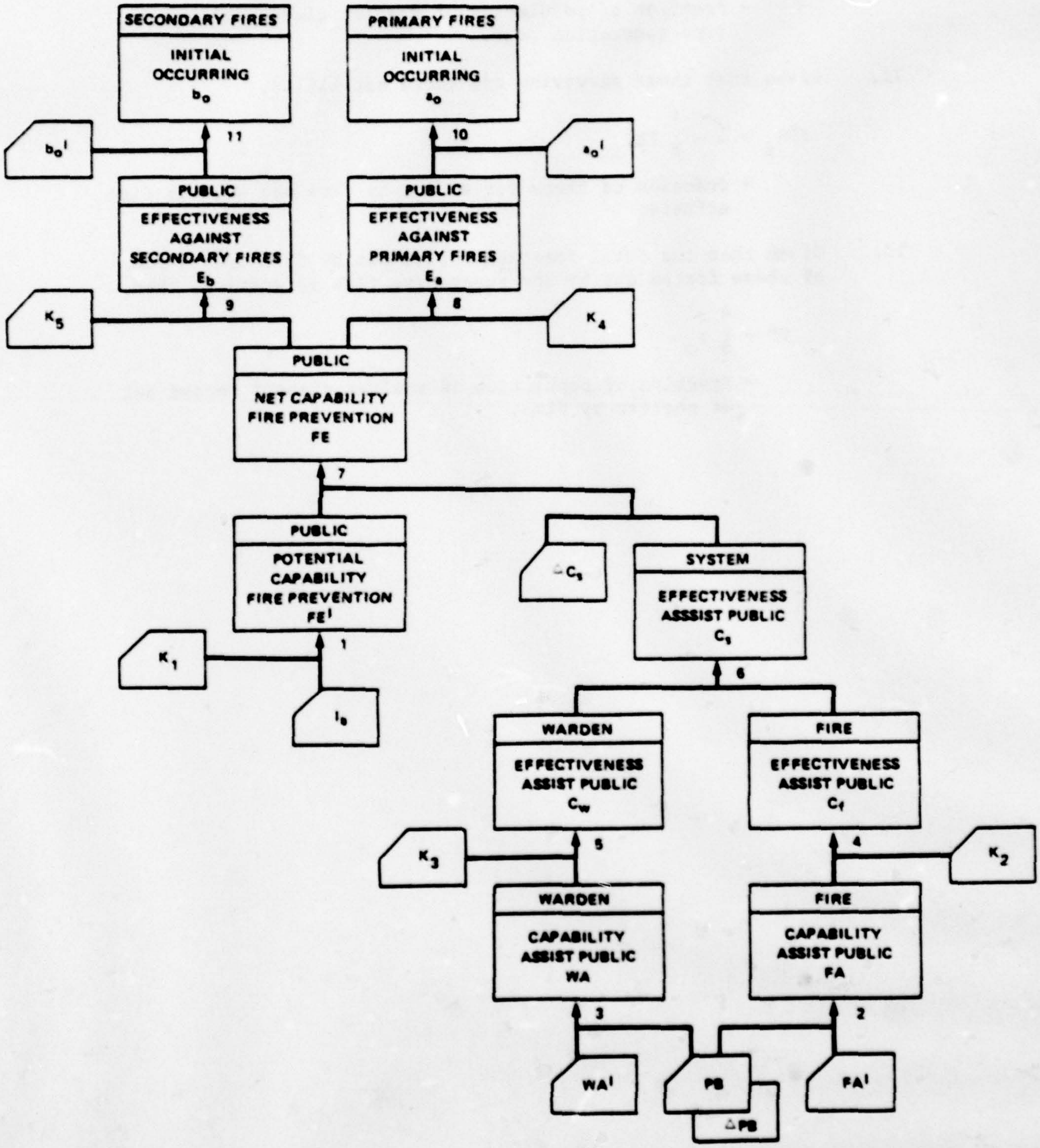
= fraction of those forced out by fire who survive fire effects.

13. Given that the total fraction forced out by fire is the sum of those forced out by the successive fire generation, then,

$$FF = \sum_{0}^{4} f_n$$

= fraction of population of shelter class i forced out of shelter by fire.

FIRE PREVENTION
OCCURRENCE OF INITIAL FIRES – a_o, b_o



FIRE PREVENTION- OCCURRENCE OF INITIAL FIRES - a_o, b_o

Concept

a_o = number of initial fires (fraction of buildings with sustained fires) resulting from exposure to the thermal pulse when fire prevention measures have been accomplished.

b_o = number of secondary fires (fraction of buildings with sustained fires) resulting from damage or from leaving buildings unattended when fire prevention measures have been accomplished.

Operation: Primary fires can be prevented by
(1) screening: opaquing windows, moving flammable materials out of possible exposure to the thermal pulse, etc., and
(2) inhibiting: treating flammable materials with ignition-retarding substances.
Secondary fires can be prevented by shutting off electric, gas, and liquid fuel supplies, by shutting down processes that involve fire, etc. Fire prevention measures would be undertaken by the public: by the residents in residential buildings and by the staffs of the users or owners of other types of facilities. The efforts of the public can be enhanced by advice and assistance from members of the civil defense organization, chiefly
(1) firefighters (professional and auxiliary) and
(2) others, included here in the term "wardens."

Analysis:

1. Given public information activities to prepare the public for attack including instruction in fire prevention, so that,

I_a = fraction of population who know about self-help fire prevention, and

K_1 = fraction of those who know who could accomplish fire prevention actions with some help. Then,

$FE' = K_1 \cdot I_a$

= fraction of population who could accomplish fire prevention with help.

2. Given that the fire service would try to help the public with fire prevention,

FA' = fraction of population with firemen who could try to help,

ΔPB = maximum change in fraction of population with firemen trying to help between
(a) not having the activity treated in operations plans, and
(b) having fully adequate treatment, and

PB = net adequacy of treatment of fire prevention activities of fire service in operations plans. Then,

$$FA = FA'\{1 - \Delta PB(1 - PB)\}$$

= fraction of population having firemen trying to help with fire prevention.

3. Given that the warden service would try to help the public with fire prevention,

WA' = fraction of population with wardens who could try to help,

ΔPB = maximum change in fraction of population with wardens trying to help between
(a) not having the activity treated in operations plans and
(b) having fully adequate treatment, and

PB = net adequacy of treatment of fire prevention activities of warden service in operations plans. Then,

$$WA = WA'\{1 - \Delta PB(1 - PB)\}$$

= fraction of population having wardens trying to help with fire prevention.

4. Given that firemen may be less than completely effective, and

K_2 = relative effectiveness of firemen. Then,

$$C_f = K_2 \cdot FA$$

= fraction of population helped in fire prevention by firemen.

5. Given that wardens may be less than completely effective, and

K_3 = relative effectiveness of wardens. Then,

$C_w = K_3 \cdot FA$

= fraction of population helped in fire prevention by wardens.

6. Given that any individual may be helped by a fireman or a warden but need not be helped by both. Then,

$C_s = C_f + C_w - C_f C_w$

= fraction of population helped in fire prevention.

7. Given that the capability of the public to achieve fire prevention depends on the amount of help they get, and

ΔC_s = maximum change in fire prevention capability of the public between
(a) not having any help from the CD organization and
(b) having fully adequate assistance. Then,

$FE = FE'\{1 - \Delta C_s(1 - C_s)\}$

8. Given that the relative effectiveness of fire prevention against primary fires would differ from that against secondary fires,

K_4 = relative effectiveness of fire prevention against primary fires. Then,

$E_a = K_4 \cdot FE$

= fraction of the number of buildings that would have been set on fire initially by primary ignitions without fire prevention that are set on fire with fire prevention.

9. Given that the relative effectiveness of fire prevention against secondary fires would differ from that against primary fires,

K_5 = relative effectiveness of fire prevention against secondary fires. Then,

$E_b = K_5 \cdot FE$

= fraction of the number of buildings that would have been set on fire initially by secondary ignitions without fire prevention that are set on fire with fire prevention.

10. Given that fire prevention can reduce the number of primary ignitions, and

a_o' = fraction of buildings set on fire by primary ignitions without fire prevention. Then,

$a_o = E_a \cdot a_o'$

= fraction of buildings set on fire by primary ignitions with fire prevention.

11. Given that fire prevention can reduce the number of secondary ignitions, and

b_o' = fraction of buildings set on fire by secondary ignitions without fire prevention. Then,

$b_o = E_b \cdot b_o'$

= fraction of buildings set on fire by secondary ignitions with fire prevention.

FIRE SUPPRESSION CAPABILITY - TOTAL - e_g

Concept

e_g = fraction of fires extinguished by fire suppression activities in fire generation g.

Operation: Uninjured occupants of shelters can suppress fires in the structures that contain the shelters under the leadership of trained shelter managers or emergent leaders. These people need support by shelter RADEF and by information from D&C. Additional fire suppression capability can be supplied by the professional fire service.

Analysis: (System tree overleaf)

1. Given people in shelters with managers. Then,

   WHR = WLR (Page B-137)

   = fraction of population with shelter managers at program completion.

2. Given that managers should be trained in shelter-based fire suppression,

   WHT_o = fraction of population with trained managers at program start, and

   ΔWHT = net additional fraction for whom managers are trained in program. Then,

   $WHT = WHT_o + \Delta WHT$

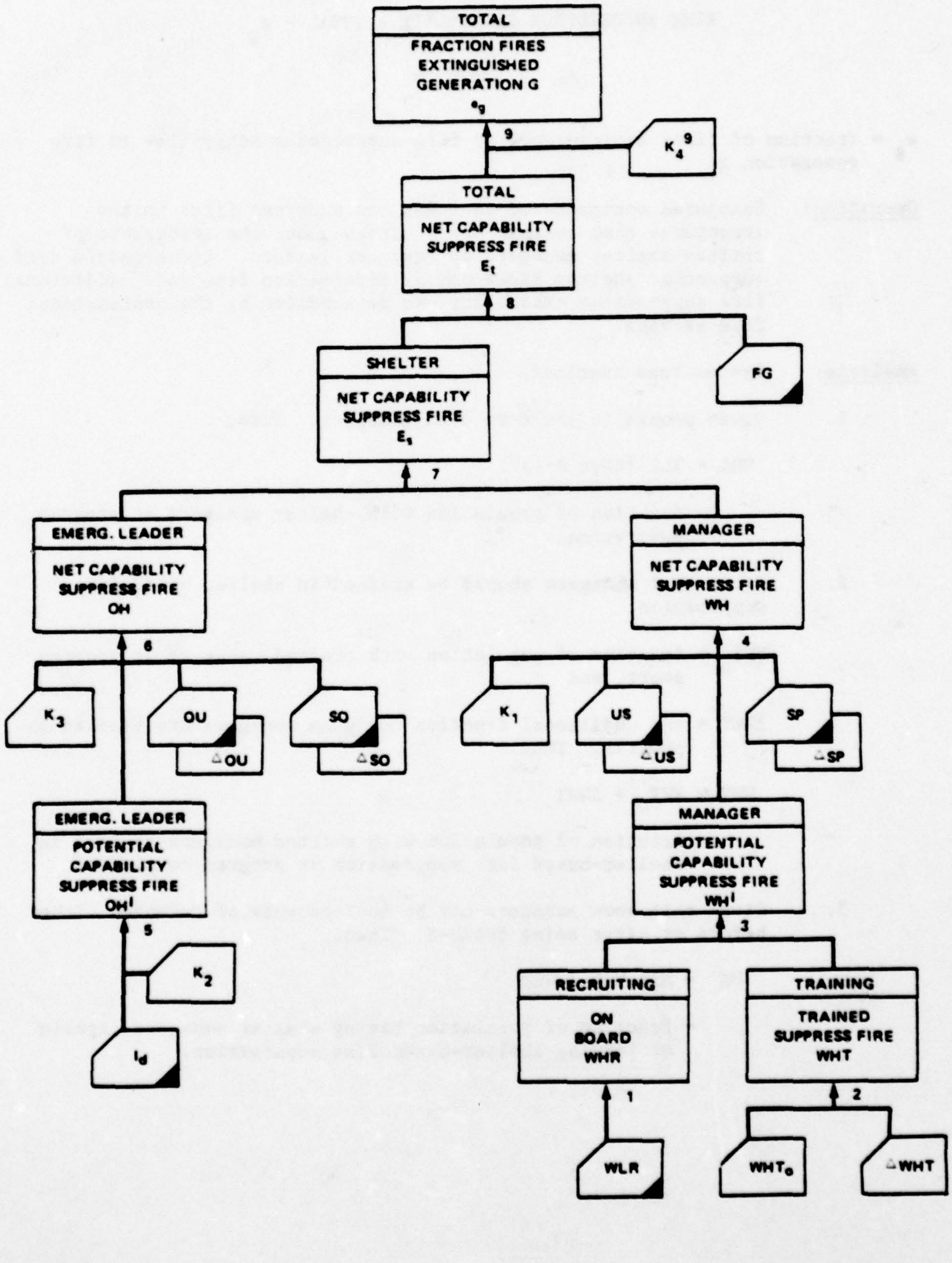
   = fraction of population with shelter managers trained in shelter-based fire suppression at program completion.

3. Given that some managers may be lost because of turnover either before or after being trained. Then,

   WH' = Min WHR : WHT

   = fraction of population having shelter managers capable of leading shelter-based fire suppression.

FIRE SUPPRESSION CAPABILITY – TOTAL – e_g



4. Given
(a) that some shelter occupants would not be effective as fire fighters because of injury, age, or other factors, and
(b) that the manager and fire fighters should have support by shelter RADEF and D&C information,

K_1 = fraction of population with managers who are effective as shelter-based fire fighters after attack effects,

ΔUS = maximum change in fire suppression capability between
(a) not having any organization shelter RADEF capability and
(b) having fully adequate organization shelter RADEF capability,

US = net monitoring capability of organization in shelter,

ΔSP = maximum change in fire suppression capability between
(a) not having any ability to receive information from D&C and
(b) having fully adequate ability to be informed, and

SP = net capability of managers to receive and understand information from D&C about fire suppression. Then,

$$WH = K_1 \cdot WH'\{1 - \Delta US(1 - US)\}\{1 - \Delta SP(1 - SP)\}$$

= fraction of population with adequate shelter-based fire suppression led by shelter managers.

5. Given public information activities to prepare the public for occupying the shelters,

I_d = fraction of the population who know about shelter-based fire suppression because of public information activities, and

K_2 = fraction of those who know who would attempt to fight fires. Then,

$$OH' = K_2 \cdot I_d$$

= fraction of the population in shelters without a trained manager who would try to fight fires.

6. Given
(a) that some shelter occupants would not be effective as fire fighters because of injury, age, or other factors and
(b) that the emergent leader and fire fighters should have support by shelter RADEF and D&C information,

K_3 = fraction of the population with emergent leaders who are effective as shelter-based fire fighters after attack,

ΔOU = maximum change in fire suppression capability between
(a) not having any emergent shelter RADEF capability and
(b) having fully adequate emergent shelter RADEF capability,

OU = net monitoring capability of emergent monitor,

ΔSO = maximum change in fire suppression capability between
(a) not having any ability to receive information from D&C and
(b) having fully adequate ability to be informed, and

SO = net capability of emergent leader to receive and understand information from D&C about fire suppression. Then,

$$OH = K_3 \cdot OH'\{1 - \Delta OU(1 - OU)\}\{1 - \Delta SO(1 - SO)\}$$

= fraction of the population with adequate shelter-based fire suppression led by emergent leaders.

7. Given that fires may be suppressed by forces led by managers or emergent leaders, then,

$$E_s = WH + OH - WH \cdot OH$$

= fraction of population with adequate shelter-based capability to suppress fires.

8. Given that fire service and shelter-based suppression capabilities are redundant, and

FG = fraction of population with adequate fire service suppression capability after attack. Then,

$$E_t = E_s + FG - E_s \cdot FG$$

= fraction of population with adequate fire suppression capability after attack.

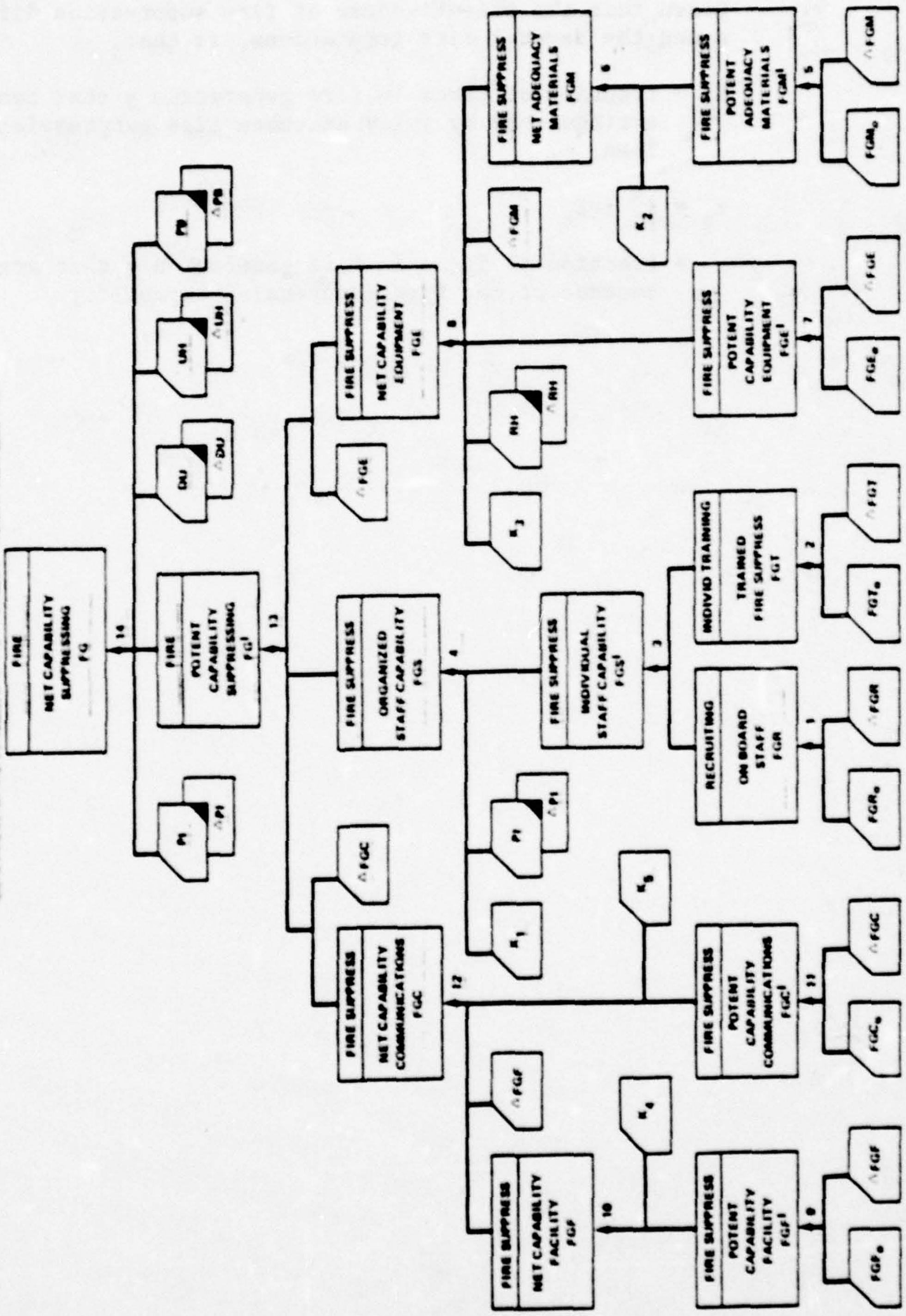
9. Given that the effectiveness of fire suppression differs among the several fire generations, so that,

E_4^g = fraction of fires in fire generation g that can be extinguished by fully adequate fire suppression capability. Then,

$$e_g = K_4^g \cdot E_t$$

= fraction of fires in fire generation g that are extinguished because of net fire suppression capability.

FIRE SUPPRESSION CAPABILITY – ORGANIZED – FG



FIRE SUPPRESSION CAPABILITY - ORGANIZED - FG

Concept

FG = net capability of the fire service to suppress fires.

Operation: The organized fire service employs trained, professional fire-fighters and fire fighting equipment to extinguish fires or to inhibit the spread of fire. They require equipment and materials, especially a supply of water.

Analysis:

1. Given a fire service,

FGR_o = fraction of population having adequate fire suppression staff at program start, and

ΔFGR = net additional fraction for whom fire staff is recruited in program. Then,

$FGR = FGR_o + \Delta FGR$

= fraction of population with adequate fire suppression staff at program completion.

2. Given on-board fire service staff that needs to be trained in fire fighting after a nuclear attack,

FGT_o = fraction of population having staff adequately trained in fire suppression at program start, and

ΔFGT = net additional fraction for whom staff is trained in program. Then,

$FGT = FGT_o + \Delta FGT$

= fraction of population having fire suppression staff adequately trained at program completion.

3. Given that some of the staff may be lost because of turnover either before or after being trained, then,

$FGS' = \text{Min } FGR : FGT$

= fraction of population having adequate fire suppression staff individually trained at program completion.

4. Given
(a) that service exercises enhance staff capability and
(b) that some of the fire staff could be incapacitated by attack effects,

ΔPI = maximum change in capability of fire suppression staff between
(a) not having any service exercise for training and
(b) having fully adequate exercise for training,

PI = net adequacy of fire service exercises, and

K_1 = fraction of fire suppression staff effective after attack effects. Then,

$$FGS = K_1 \cdot FGS'\{1 - \Delta PI(1 - PI)\}$$

= fraction of population having effective, competent fire suppression staff after attack.

5. Given that fire fighters need materials both for operation of their equipment and for use in fire suppression,

FGM_o = fraction of population having adequate supplies of fire suppression materials at program start, and

ΔFGM = net additional fraction for whom materials are procured in program. Then,

$$FGM' = FGM_o + \Delta FGM$$

= fraction of population having adequate fire suppression materials at program completion.

6. Given that some fire suppression materials may be destroyed or rendered unavailable by attack effects so that,

K_2 = fractional survival of fire suppression materials after attack effects. Then,

$$FGM = K_2 \cdot FGM'$$

= fraction of population having adequate fire suppression materials after attack.

7. Given that fire fighters need equipment for fire suppression,

FGE_o = fraction of population having fire suppression equipment at program start, and

ΔFGE = net additional fraction for whom equipment is procured in program. Then,

$FGE' = FGE_o + \Delta FGE$

= fraction of population having adequate fire suppression equipment at program completion.

8. Given
(a) that some equipment may be destroyed or rendered unavailable by attack effects and
(b) that the capability of equipment depends on having materials for its operation and a supply of water,

K_3 = fractional availability of fire suppression equipment after attack effects,

ΔFGM = maximum change in capability of fire suppression equipment between
(a) not having any materials and
(b) having fully adequate supply of materials,

ΔRH = maximum change in capability of fire suppression equipment between
(a) not having any resource service capability to operate water facility and
(b) fully adequate resource capability to operate water facility, and

RH = net capability of resource service to operate water facility. Then,

$$FGE = K_3 \cdot FGE'\{1 - \Delta FGM(1 - FGM)\}\{1 - \Delta RH(1 - RH)\}$$

9. Given that fire service communications may depend on having communications between the forces on the fire ground and dispatchers in the fire stations,

FGF_o = fraction of population having fire service facilities at program start, and

ΔFGF = net additional fraction for whom facilities are procured in program. Then,

$FGF' = FGR_o + \Delta FGF$

= fraction of population having adequate fire service facilities at program completion.

10. Given that some fire service facilities can be destroyed or rendered not operational because of attack effects so that,

K_4 = fractional survival of fire service facilities after attack effects. Then,

$FGF = K_4 \cdot FGF'$

= fraction of population having adequate fire service facilities operable after attack.

11. Given that fire fighters need communications,

FGC_o = fraction of population having adequate fire service communications at program start, and

ΔFGC = net additional fraction for whom communications are procured in program. Then,

$FGC' = FGC_o + \Delta FGC$

= fraction of population having adequate fire service communications at program completion.

12. Given
(a) that fire service communications can be destroyed by attack effects and
(b) that communications depend on having fire stations,

K_5 = fractional survival of fire service communications after attack effects,

ΔFGF = maximum change in fire service communications capability between
(a) not having any fire service facilities and
(b) having fully adequate fire service facilities. Then,

$$FGC = K_5 \cdot FGC'\{1 - \Delta FGF(1 - FGF)\}$$

= fraction of population having adequate fire service communications capability after attack.

13. Given
(a) that the fire suppression capability of the fire service staff can be enhanced by having equipment operating and communications capabilities and
(b) it would be limited by the lesser of them,

ΔFGE = maximum change in suppression capability of fire service between
(a) not having any equipment support for staff and
(b) having fully adequate equipment capability, and

ΔFGC = maximum change in suppression capability of fire service between
(a) not having any communications support for staff and
(b) having fully adequate communications. Then,

$$FG' = FGS \cdot \mathrm{Min}\{1 - \Delta FGE(1 - FGE)\}:\{1 - \Delta FGC(1 - FGC)\}$$

= fraction of population having adequate fire service suppression capability after attack if fully supported.

14. Given that the fire service should be supported,

ΔPI = maximum change in fire suppression capability between
(a) not having any exercise of the CD organization and
(b) having fully adequate exercises,

PI = net adequacy of organization exercises,

ΔDU = maximum change in suppression capability of fire service between
(a) not having any D&C information support and
(b) having fully adequate information support,

DU = net adequacy of D&C system information support,

ΔUH = maximum change in suppression capability of fire service between
(a) not having any self-help RADEF capability and
(b) having fully adequate self-help RADEF capability

UH = net fire service self-help RADEF capability,

ΔPB = maximum change in fire suppression capability of fire service between
(a) not having adequate treatment of the activity in operations plans and
(b) having fully adequate treatment, and

PB = net adequacy of treatment of fire service suppression activities in operations plans. Then,

$$FG = FG'\{1 - \Delta PI(1 - PI)\}\{1 - \Delta DU(1 - DU)\}\{1 - \Delta UH(1 - UH)\}\{1 - \Delta PB(1 - PB)\}$$

= net capability of fire service to suppress fires after attack.

PUBLIC PREPAREDNESS - SELF HELP - I_a

Concept

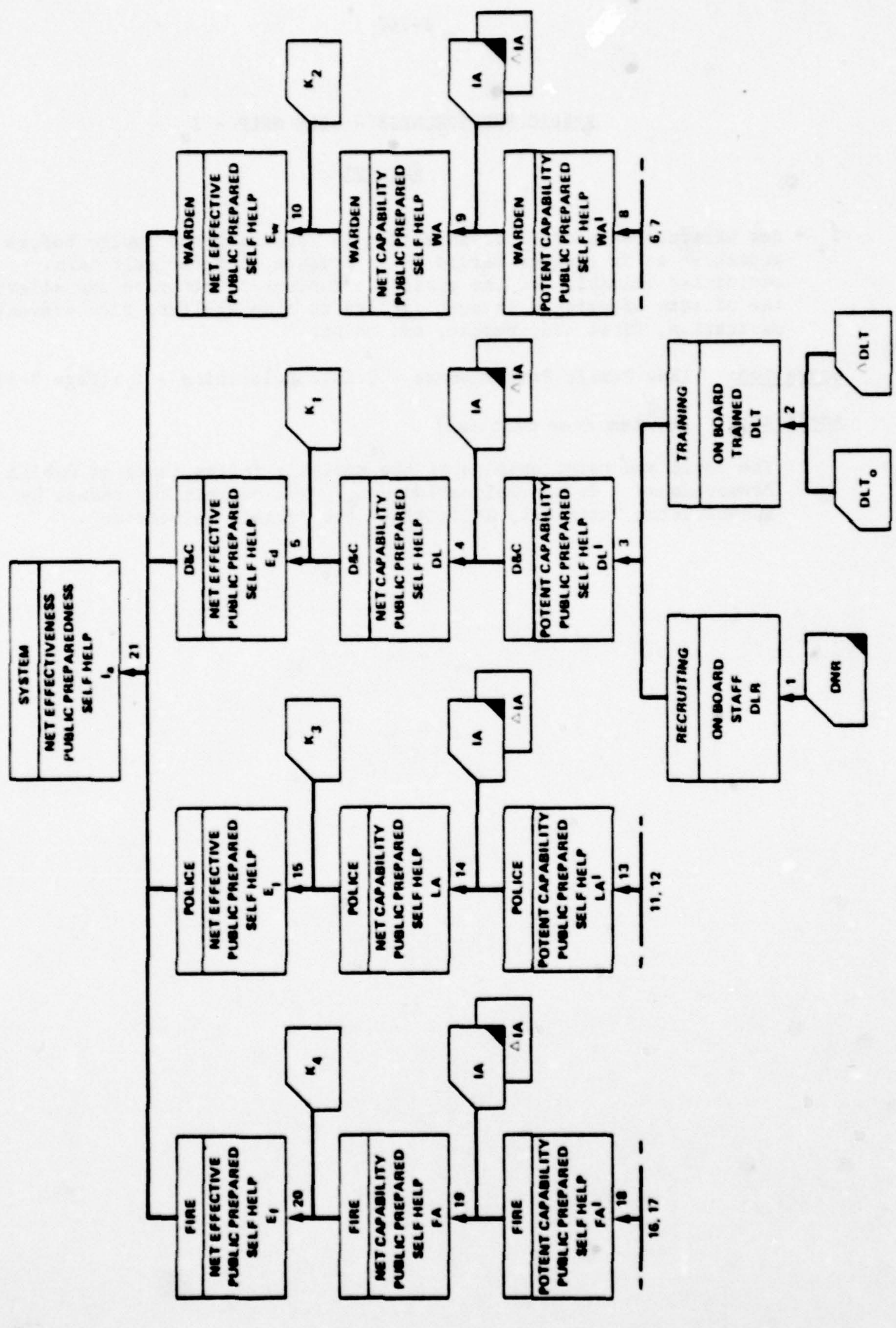
I_a = net effectiveness of CD organization in educating the public before an attack -- as in a surge period -- to prepare them for self help: activities suitable for the public to conduct to mitigate and alleviate the effects of attacks in such matters as home shelter, fire prevention, sanitation, first aid, rescue, and so on.

Operation: (See Public Preparedness - Crisis Relocation - I_c)(Page B-83)

Analysis: (System tree overleaf)

The logic and relationships of the analysis follow those of Public Preparedness - Crisis Relocation - I_c. The definitions change by substituting "self-help activities" for "crisis relocation".

PUBLIC PREPAREDNESS – SELF HELP–I_a



PUBLIC INFORMATION MATERIALS - SELF HELP - IA

Concept

IA = net adequacy of informational materials prepared for use in public preparedness education in actions suitable for the public to take to mitigate and alleviate the effects of attack in such matters as home shelter, fire prevention, sanitation, first aid, rescue, and so on.

Operation: Public information materials are prepared by personnel of an EPI staff element of the preparedness system organization trained for assignment to their positions and arrangements are concluded for dissemination of these materials. Information for these materials can be supplied by Federal and State CD.

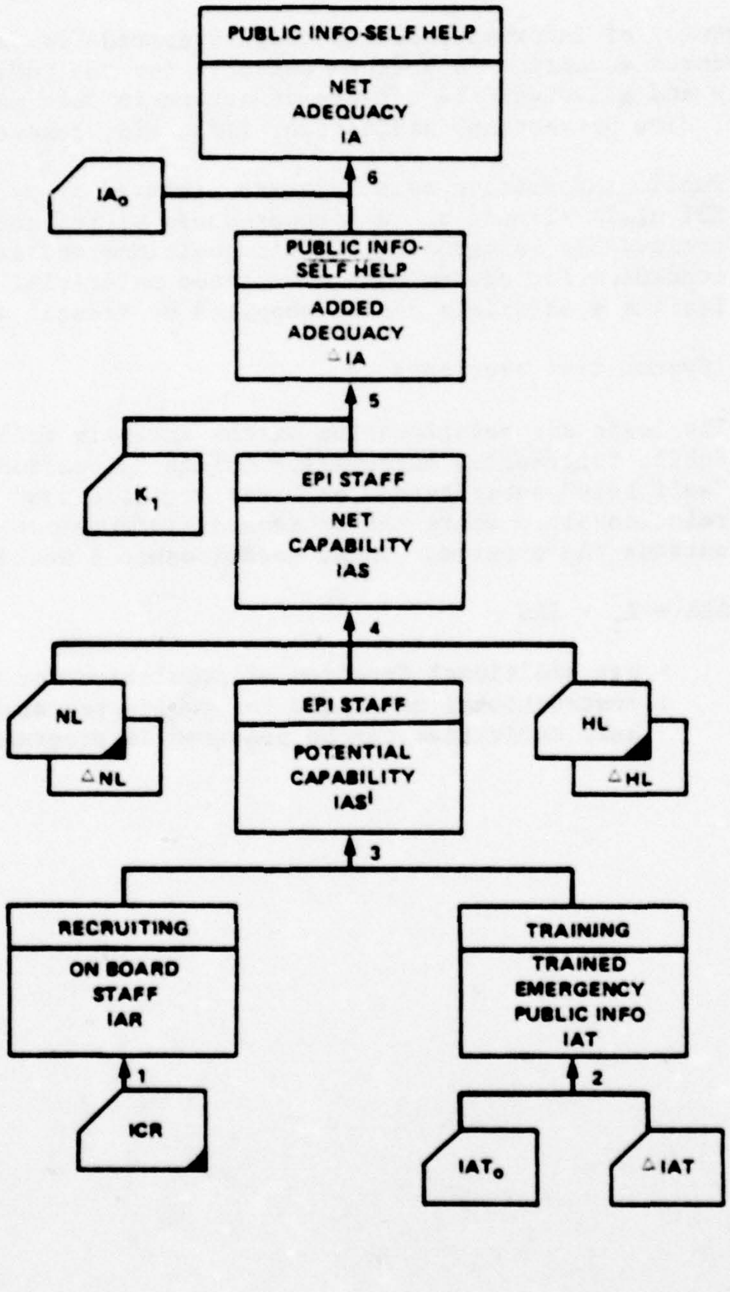
Analysis: (System tree overleaf)

The logic and relationships of the analysis follow those of Public Information Materials - Crisis Relocation - IC, with "self help" substituted for "crisis relocation" except in relationship 5 where the sources of information are found outside the program. Then, relationship 5 would become.

$\Delta IA = K_1 \cdot IAS$

= net additional fraction of population for whom adequate instructional materials for public preparedness for self help activities can be prepared in program.

PUBLIC INFORMATION MATERIALS – SELF HELP – IA



SHELTER RADEF - ORGANIZED - US

Concept

US = net capability of CD organization personnel in shelters to monitor radiation intensity or dose in public shelter.

Operation: Radiation measuring instruments are placed in public shelters together with instructions for their use. Monitors are trained for assignment in public shelters. Managers are given some training in RADEF. Policemen who control the movement to shelter will enter the public shelters; some of them will have had monitoring training and may bring self-help RADEF instruments to shelter.

Analysis: (System tree overleaf)

1. Given monitors for public shelters,

UBR_o = fraction of population having shelter monitors at program start, and

ΔUBR = net additional fraction for whom monitors are brought on board during program. Then,

$UBR = UBR_o + \Delta UBR$

= fraction of population having shelter monitors at program completion.

2. Given on-board shelter monitors who should be trained,

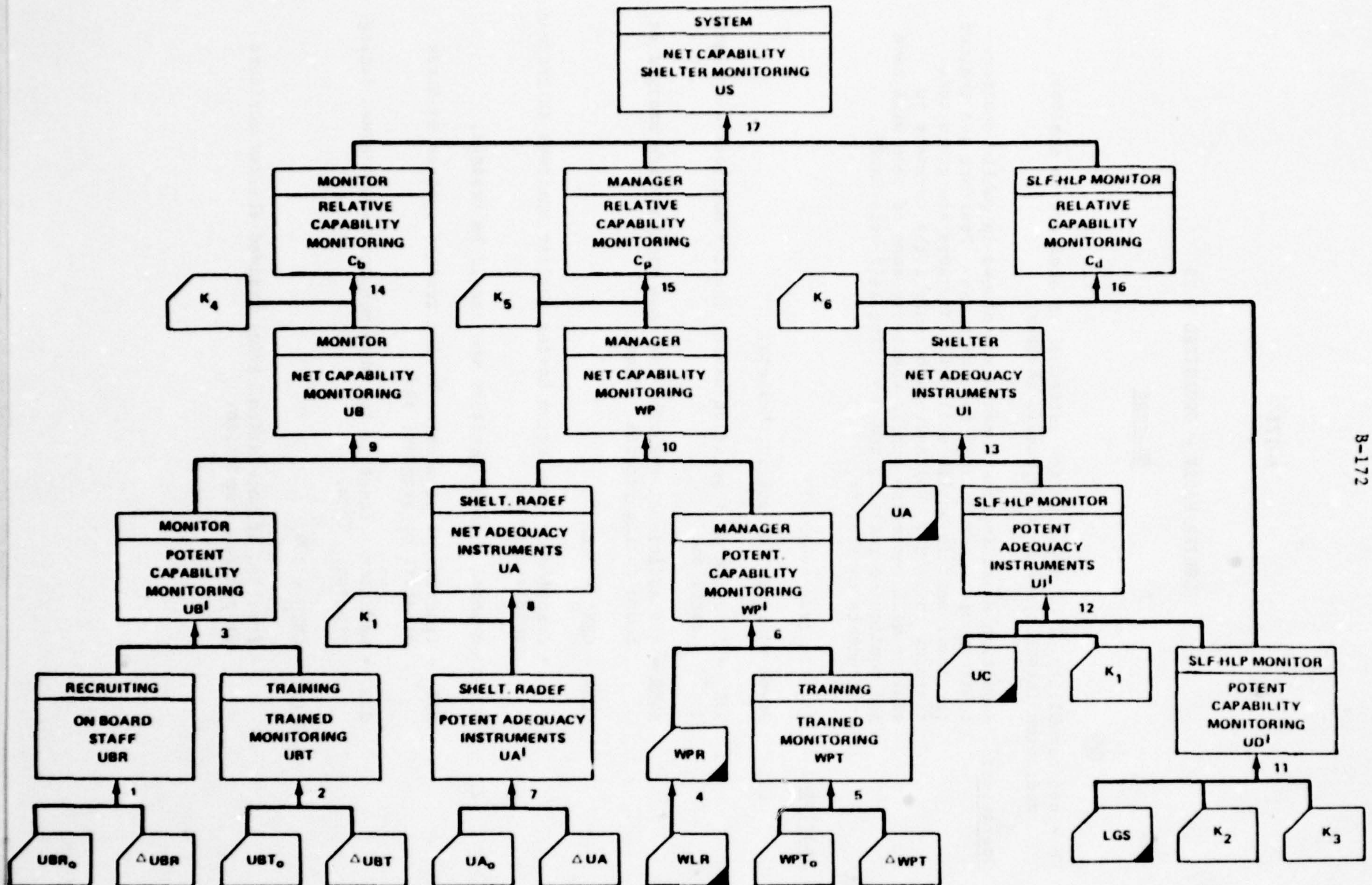
UBT_o = fraction of population having trained shelter monitors at start of program, and

ΔUBT = additional fraction for whom monitors are trained during program. Then,

$UBT = UBT_o + \Delta UBT$

= fraction of population having trained shelter monitors at program completion.

SHELTER RADEF – ORGANIZED – US



3. Given that some shelter monitors will be lost because of turnover either before or after being trained, then,

$UB' = \text{Min } UBR : UBT$

= fraction of population having capable shelter monitors at program completion.

4. Given managers for public shelters so that

$WPR = WLR$ (Page B-137)

= fraction of population having shelter managers on-board at program completion.

5. Given that shelter managers may be trained in monitoring,

WPT_o = fraction of population having managers trained in monitoring at start of program, and

ΔWPT = net additional fraction for whom managers are trained in program. Then,

$WPT = WPT_o + \Delta WPT$

= fraction of population having trained shelter managers at program completion.

6. Given that some managers may be lost because of turnover either before or after being trained, then,

$WP' = \text{Min } WPR : WPT$

= fraction of population having managers capable of monitoring at program completion.

7. Given that radiation measuring instruments may be placed in public shelters,

UA_o = fraction of population having instruments in public shelters at program start, and

ΔUA = net additional fraction for whom instruments are placed in shelters in program. Then,

$UA' = UA_o + \Delta UA$

= fraction of population having instruments in public shelters at program completion.

8. Given that not all instruments are fully reliable so that,

K_1 = fraction of instruments in public shelters that are reliable. Then,

$UA = K_1 \cdot UA'$

= fraction of population having reliable instruments in public shelters at program completion.

9. Given that it is logical for shelter monitors to be assigned to shelters in which instruments have been placed, then,

$UB = \text{Min } UB' : UA$

10. Given that managers may be assigned to shelters on the basis of factors other than having instruments in the shelters. Then,

$WP = WP' \cdot UA$

= fraction of population having adequate shelter manager monitoring capability in public shelters.

11. Given
(a) that traffic control police will enter the public shelters and
(b) that some of them are trained self-help RADEF monitors,

LGS = fraction of population having adequate police traffic control staff at program completion (Page B-139),

K_2 = fraction of traffic policemen who are monitors, and

K_3 = ratio of traffic policemen to number of police shelters. Then,

$UD' = K_2 \cdot K_3 \cdot LGS$

= fraction of population having police monitors in public shelters.

12. Given
(a) that police monitors may bring their self-help instruments to shelter and
(b) that not all of these instruments would be reliable,

UC = fraction of population having self-help RADEF instruments assigned to police traffic control forces at program completion, and

K_1 = fraction of self-help instruments that are reliable. Then,

$UI' = \text{Min}\ (K_1 \cdot UC) : UD'$

= fraction of population having reliable police self-help instruments in public shelters.

13. Given that the shelters may have shelter instruments or police instruments but need not have both,

$UI = UA + UI' - UA \cdot UI'$

= fraction of population having instruments available to police monitors in public shelters.

14. Given that shelter monitors may not be fully capable in monitoring so that,

K_4 = relative monitoring capability of shelter monitors. Then,

$C_b = K_4 \cdot UB$

= fraction of population with fully capable shelter monitors.

15. Given that shelter managers may not be fully capable in monitoring so that,

K_5 = relative monitoring capability of shelter managers. Then,

$C_p = K_5 \cdot WP$

= fraction of population with fully capable shelter managers.

16. Given
(a) that a police monitoring capability requires both monitors and instruments and
(b) that police monitors may not be fully capable in monitoring so that,

K_6 = relative monitoring capability of police monitors. Then,

$C_d = K_6(\text{Min UI : UD}')$

= fraction of population with fully capable police monitors in public shelters.

17. Given that occupants of public shelters should have a monitoring capability by a monitor, a manager, or a police monitor but need not have more than one,

$US = C_b + C_p + C_d - C_bC_p - C_bC_d - C_pC_d + C_bC_pC_d$

= fraction of population having adequate CD organization monitoring capability in public shelters.

SHELTER RADEF - EMERGENT - OU

Concept

OU = Net capability of a shelter occupant, not trained in radiation monitoring, to measure dose rate and accumulated dose to aid both in in-shelter operations and in shelter-based operations outside the shelter.

Operation: A shelter not having a member of the CD organization but having RADEF instruments may have a member of the public by his own initiative, because of public preparedness EPI, or upon advice from D&C, open the instrument package and use the instruments in accordance with the instructions included in the package.

Analysis: (System tree overleaf)

1. Given EPI activities to prepare the public for going to shelter and a shelter without CD organization personnel trained in monitoring, and

   I_d = net effectiveness of EPI in educating the public about in-shelter monitoring. Then,

   $OU' = I_d$

   = fraction of shelter class population with emergent monitor trying to use the instrument given reliable instruments and information from D&C.

2. Given emergent monitors and reliable instruments in the shelters both at random,

   K = relative ability of an emergent monitor to measure radiation flux,

   UA = fraction of shelter class population with reliable instruments in shelter (from UA - Page B-174),

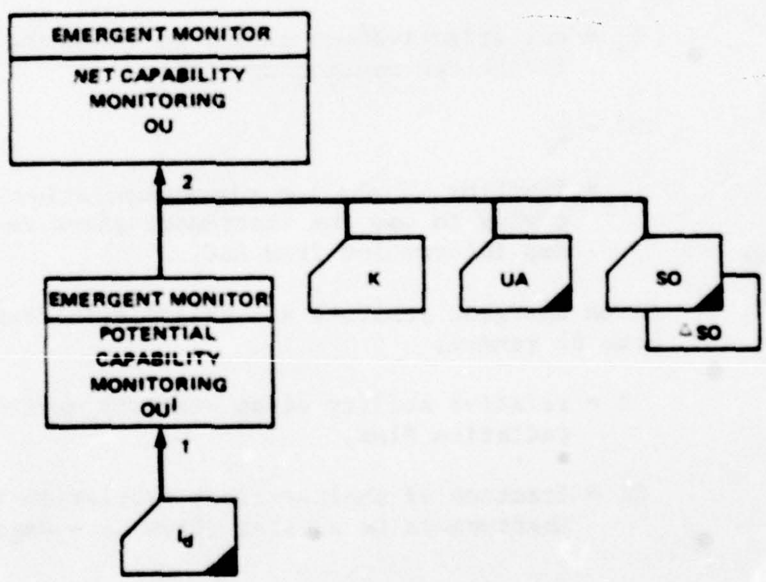
ΔSO = maximum change in capability of an emergent monitor between
(a) not having any capability to receive information from D&C and
(b) having fully adequate capability to receive information from D&C, and

SO = net capability of emergent monitor to receive and understand information from D&C. Then,

$$OU = K \cdot OU' \cdot UA\{1 - \Delta SO(1 - SO)\}$$

= net monitoring capability of an emergent monitor.

SHELTER RADEF – EMERGENT – OU



SELF-HELP RADEF - UH

Concept

UH = net capability of an operating staff to monitor radiation intensity and dose and to interpret the readings in terms appropriate for the operation being conducted.

Operation: Every emergency operation being conducted after a nuclear attack needs a capability to measure radiation fields: first, to identify the presence or absence of radiation where the operation is being conducted and second, to determine whether the operation can continue with due regard for the safety of the personnel.

Analysis: (System tree overleaf)

1. Given units or services that may be subjected to fallout when operating,

UDR_o = fraction of population having adequate self-help monitors for the units at program start, and

ΔUDR = net additional fraction for whom monitors are recruited for the units in program. Then,

$$UDR = UDR_o + \Delta UDR$$

= fraction of population having adequate self-help monitors for the units at program completion.

2. Given on-board self-help monitors who should be trained,

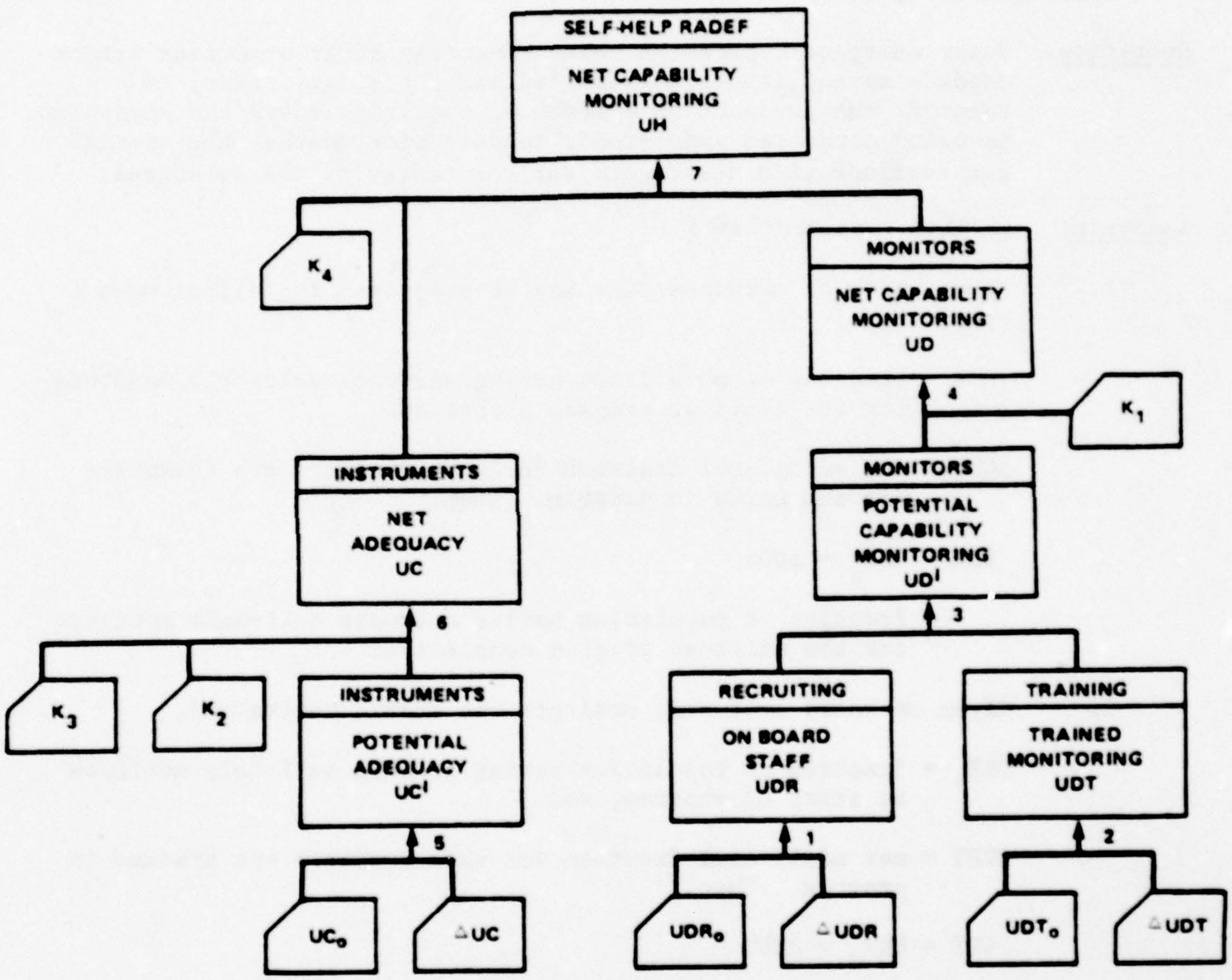
UDT_o = fraction of population having trained self-help monitors at start of program, and

ΔUDT = net additional fraction for whom monitors are trained in program. Then,

$$UDT = UDT_o + \Delta UDT$$

= fraction of population having adequate trained self-help monitors for the units at program completion.

SELF-HELP RADEF – UH



3. Given that some self-help monitors may be lost because of turnover either before or after being trained. Then,

$UD' = \text{Min } UDR : UDT$

= fraction of population having adequate competent self-help monitors for the units at program completion.

4. Given that some self-help monitors may be incapacitated because of attack effects so that,

K_1 = fraction of self-help monitors effective after attack effects. Then,

$UD = K_1 \cdot UD'$

= fraction of population having adequate self-help monitors after attack.

5. Given that self-help monitors need radiation measuring instruments,

UC_o = fraction of population for whom self-help instruments are on hand at start of program, and

ΔUC = net additional fraction for whom instruments are procured in program. Then,

$UC' = UC_o + \Delta UC$

= fraction of population for whom self-help instruments are on hand at program completion.

6. Given
(a) that some instruments are not fully reliable and
(b) that some may be destroyed or rendered unavailable or unreliable because of attack effects,

K_2 = fraction of self-help instruments available after attack effects, and

K_3 = fraction of available self-help instruments reliable after attack effects. Then,

$UC = K_2 \cdot K_3 \cdot UC'$

= fraction of population having adequate, reliable self-help instruments after attack.

7. Given
   (a) that monitors require instruments
   (b) that some self-help monitors may not be fully capable, and

   K_4 = relative monitoring capability of self-help monitors. Then,

   $UH = K_4(\text{Min } UC : UD)$

   = fraction of population having adequate self-help RADEF capability for units or services that may be subject to radiation when operating.

D&C - ACQUIRE INPUT INFORMATION - DZD

Concept

DZD = net capability of CD organization to acquire data about the situation and to communicate these data to D&C as basis for preparation and dissemination of information and guidance to the CD organization and the public.

Operation: Each element of the CD organization can observe and report on any feature of the situation: condition of the people, natural and attack environment, condition of the CD system, and so on. The effectiveness of the several elements of the organization can differ with respect to the subject matter of the data to be reported.

Analysis: (System tree overleaf)

1. Given fire services,

   FIS = fraction of population with adequate fire service staff trying to acquire data after attack given adequate operations plans,

   ΔFIC = maximum change in data acquisition capability of fire service between
   (a) not having any service communications capability and
   (b) having fully adequate service communications capability, and

   FIC = fraction of population with adequate fire service communications capability after attack. Then,

   $$FI' = FIS\{1 - \Delta FIC(1 - FIC)\}$$

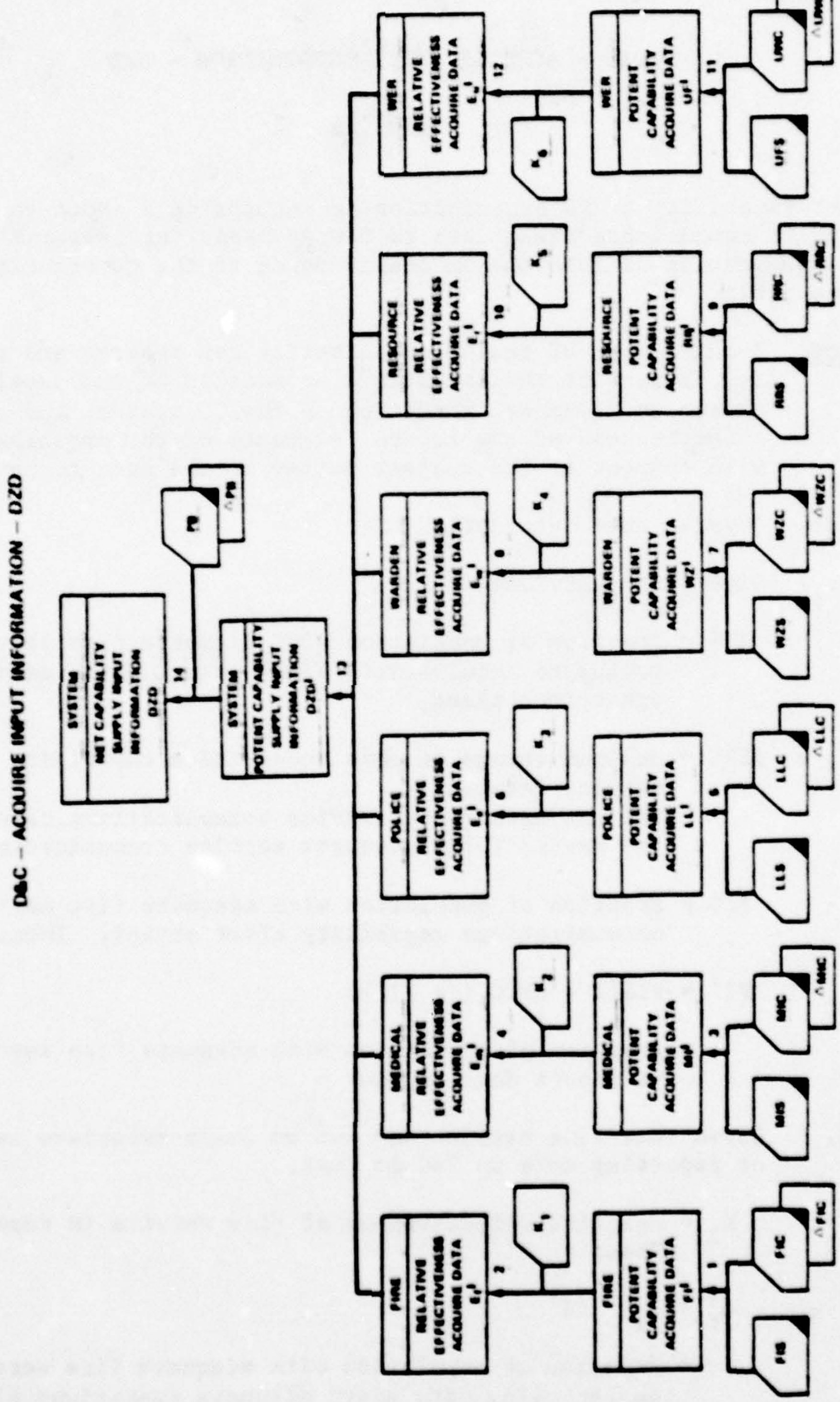
   = fraction of population with adequate fire service capability to report data to D&C.

2. Given that fire service may not be fully effective in observing or reporting data to D&C so that,

   K_1 = relative effectiveness of fire service in reporting data. Then,

   $$E_f' = K_1 \cdot FI'$$

   = fraction of population with adequate fire service effectiveness in reporting data given adequate operations plans.


D&C – ACQUIRE INPUT INFORMATION – DZD
SYSTEM
NET CAPABILITY SUPPLY INPUT INFORMATION DZD
14
PB
ΔPB
SYSTEM
POTENT CAPABILITY SUPPLY INPUT INFORMATION DZD'
13
FIRE
RELATIVE EFFECTIVENESS ACQUIRE DATA
2
FIRE
POTENT CAPABILITY ACQUIRE DATA
1
FIS
FIC
ΔFIC
MEDICAL
RELATIVE EFFECTIVENESS ACQUIRE DATA
4
MEDICAL
POTENT CAPABILITY ACQUIRE DATA
3
MIS
MIC
ΔMIC
POLICE
RELATIVE EFFECTIVENESS ACQUIRE DATA
6
POLICE
POTENT CAPABILITY ACQUIRE DATA
5
LLS
LLC
ΔLLC
WARDEN
RELATIVE EFFECTIVENESS ACQUIRE DATA
8
WARDEN
POTENT CAPABILITY ACQUIRE DATA
7
WZS
WZC
ΔWZC
RESOURCE
RELATIVE EFFECTIVENESS ACQUIRE DATA
10
RESOURCE
POTENT CAPABILITY ACQUIRE DATA
9
RRS
RRC
ΔRRC
WER
RELATIVE EFFECTIVENESS ACQUIRE DATA
12
WER
POTENT CAPABILITY ACQUIRE DATA
11
UFS
URC
ΔURC

3. Given a medical service,

MIS = fraction of population with adequate medical service staff trying to acquire data after attack given adequate operations plans,

ΔMIC = maximum change in data acquisition capability of medical service between
(a) not having any service communications capability and
(b) having fully adequate service communications capability, and

MIC = fraction of population with adequate medical service communications capability after attack. Then,

$$MI' = MIS\{1 - \Delta MIC(1 - MIC)\}$$

= fraction of population having adequate medical service capability to report data.

4. Given that the medical service may not be fully effective in reporting data so that,

K_2 = relative effectiveness of medical service in reporting data. Then,

$$E_m' = K_2 \cdot MI'$$

= fraction of population having adequate medical service effectiveness in reporting data given adequate operations plans.

5. Given a police service,

LLS = fraction of population with adequate police service staff trying to acquire data after attack given adequate operations plans,

ΔLLC = maximum change in data acquisition capability of police service between
(a) not having any service communications capability and
(b) having fully adequate service communications capability, and

LLC = fraction of population with adequate police communications after attack. Then,

$LL' = LLS\{1 - \Delta LLC(1 - LLC)\}$

= fraction of population with adequate police service capability to report data.

6. Given that the police service may not be fully effective in reporting data so that,

K_3 = relative effectiveness of police service in reporting data. Then,

$E'_{\ell} = K_3 \cdot LL'$

= fraction of population having adequate police service effectiveness in reporting data given adequate operations plans.

7. Given a warden service,

WZS = fraction of population with adequate warden staff trying to acquire data after attack given adequate operations plans,

ΔWZC = maximum change in data acquisition capability of warden service between
(a) not having any service communications capability and
(b) having fully adequate service communications capability, and

WZC = fraction of population with adequate warden communications capability after attack. Then,

$WZ' = WZS\{1 - \Delta WZC(1 - WZC)\}$

= fraction of population with adequate warden service capability to report data.

8. Given that the warden service may not be fully effective in reporting data so that,

K_4 = relative effectiveness of warden service in reporting data. Then,

$E'_w = K_4 \cdot WZ'$

= fraction of population with adequate warden service effectiveness in reporting data given adequate operations plans.

9. Given a resource service,

RRS = fraction of population having adequate resource service staff trying to acquire data after attack given adequate operations plans,

ΔRRC = maximum change in data acquisition capability of resource service between
(a) not having any service communications capability and
(b) having fully adequate service communications capability, and

RRC = fraction of population with adequate resource service communications capability after attack. Then,

$$RR' = RRS\{1 - \Delta RRC(1 - RRC)\}$$

= fraction of population with adequate resource service capability to report data.

10. Given that the resource service may not be fully effective in reporting data so that,

K_5 = relative effectiveness of resource service in reporting data. Then,

$$E'_r = K_5 \cdot RR'$$

= fraction of population having adequate resource service effectiveness in reporting data given adequate operations plans.

11. Given weapons effects reporting stations (WERs),

UFS = fraction of population with adequate WER staff trying to acquire data after attack given adequate operations plans,

ΔUWC = maximum change in data acquisition capability of WERs between
(a) not having any service communications capability and
(b) having fully adequate service communications capability, and

UWC = fraction of population with adequate Area RADEF communications capability after attack. Then,

$$UF' = UFS\{1 - \Delta UWC(1 - UWC)\}$$

= fraction of population having adequate WER capability to report data.

12. Given that WERs may not be fully effective in reporting data so that,

K_6 = relative effectiveness of WERs in reporting data. Then,

$E'_u = K_6 \cdot UF'$

= fraction of population having adequate WER effectiveness in reporting data given adequate operations plans.

13. Given that the same data may, but need not, be reported to D&C by more than one element of the organization (the capabilities are redundant). Then,

$$
\begin{aligned}
DZD' = {} & E'_f + E'_m + E'_\ell + \cdots \\
& - E'_f E'_m - E'_f E'_\ell - \cdots \\
& + E'_f E'_m E'_\ell + E'_f E'_m E'_w + \cdots \\
& - E'_f E'_m E'_\ell E'_w - E'_f E'_m E'_\ell E'_r - \cdots \\
& + E'_f E'_m E'_\ell E'_w E'_r + \cdots \\
& - E'_f E'_m E'_\ell E'_w E'_r E'_u
\end{aligned}
$$

= fraction of population having adequate effectiveness in reporting data given adequate operations plans.

14. Given that data reporting should be treated in operations plans,

ΔPB = maximum change in data reporting capability between
(a) not having the activity adequately treated in operations plans and
(b) having fully adequate treatment, and

PB = net adequacy of treatment of data reporting in operations plans. Then,

$DZD = DZD'\{1 - \Delta PB(1 - PB)\}$

= fraction of population having fully adequate effectiveness of the capability of the CD organization to acquire and report input data for D&C.

SECTION B.5

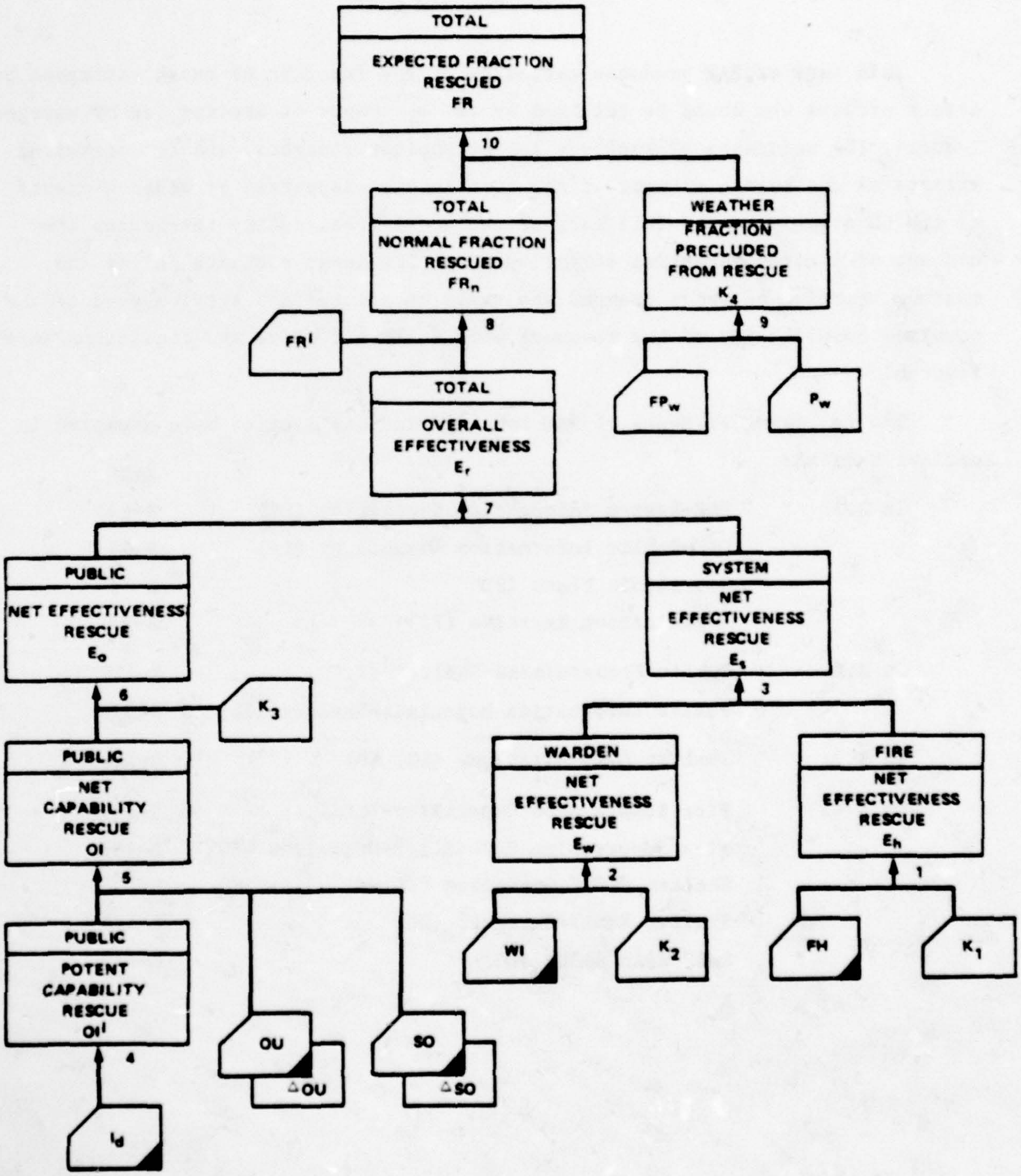
FRACTION RESCUED (FR)

This part of PAM produces estimates of the fraction of those entrapped by attack effects who could be released by (a) occupants of shelter led by emergent leaders, (b) occupants of shelters led by shelter managers, and (c) organized efforts of the rescue element of the fire service supported by other elements of the CD organization. This part of the model specifically introduces the concept of limited potential effectiveness. The input estimate FR' is the maximum fraction of those trapped who could be rescued and survive even if the combined capabilities of the rescuers were fully effective and conditions were favorable.

The following elements of PAM included in this section have appeared in earlier sections:

		Page
In B.1:	D&C-System Information Capability (DZ)	B-63
	D&C-Public Information Capability (DS)	B-69
	Operations Plans (PB)	B-75
	Organization Exercise (PI)	B-97
In B.2:	Public Preparedness-Shelter (I_d)	B-129
	Public Information Materials-Shelter (ID)	B-131
In B.3:	Shelter Communications (SO, SP)	B-141
In B.4:	Fire Suppression Capability-Total (e_g)	B-155
	Fire Suppression Capability-Organized (FG)	B-161
	Shelter RADEF-Organized (US)	B-171
	Shelter RADEF-Emergent (OU)	B-177
	Self-Help RADEF (UH)	B-179

FRACTION RESCUED – FR



FRACTION RESCUED - FR

Concept

FR = fraction rescued of the people who are trapped because of attack effects.

Operation: Some people would be trapped because of the collapse of structures and debris resulting from attack effects. These people could be released by the efforts of an organized rescue service operating from outside the damaged area and by the efforts of shelter occupants operating from the shelters under the leadership either of a shelter manager or of an emergent leader. Heavy rescue requiring equipment such as cranes would be performed only by the rescue service.

Analysis:

1. Given a rescue service that is an element of the fire service so that,

   FH = fraction of population with fire service trying to release trapped, and

   K_1 = relative effectiveness of fire service in releasing trapped people. Then,

   $E_h = K_1 \cdot FH$

   = fraction of population having adequate fire service effectiveness in rescuing.

2. Given shelter managers so that,

   WI = fraction of population with shelter managers trying to release trapped people with resources found in shelters, and

   K_2 = relative effectiveness of shelter-based rescue under leadership of manager. Then,

   $E_w = K_2 \cdot WI$

   = fraction of population having adequate manager-led, shelter-based rescue effectiveness.

3. Given that an individual could be rescued by a manager or the fire service but need not be rescued by both, then,

   $E_s = E_h + E_w - E_h E_w$

   = fraction of population having adequate effectiveness of the CD organization in rescue.

4. Given public information activities to prepare the public for shelter-based operations including rescue so that,

$OI' = I_d$

= fraction of population who would have emergent leaders trying to conduct shelter-based rescue given support.

5. Given
(a) that emergent leaders would have increased capability if supported and
(b) that without CD organization personnel in shelters they would have to rely on emergent monitors

ΔOU = maximum change in capability of public to rescue trapped people between
(a) not having any emergent monitoring capability and
(b) having fully adequate emergent monitoring capability,

OU = net monitoring capability of emergent monitors,

ΔSO = maximum change in capability of public to rescue trapped people between
(a) not having any D&C public information and
(b) having fully adequate public information communications, and

SO = net capability of D&C public information communications to emergent leaders. Then,

$$OI = OI'\{1 - \Delta OU(1 - OU)\}\{1 - \Delta SO(1 - SO)\}$$

= fraction of population having emergent leaders trying to release trapped people.

6. Given that emergent leaders may not be fully effective so that,

K_3 = relative effectiveness of emergent leaders in releasing trapped people. Then,

$$E_o = K_3 \cdot ID$$

= fraction of population having adequate emergent leader effectiveness in shelter-based rescue.

7. Given that an individual could be rescued by the CD organization or by an emergent leader but need not be rescued by both. Then,

$$E_r = E_s + E_o - E_s E_o$$

= fraction of population having adequate overall effectiveness in rescue.

8. Given that some trapped people could not be rescued in time to save their lives no matter what rescue capability was available, so that,

FR' = maximum fraction of those trapped who could be rescued in favorable weather if overall capability were fully effective. Then,

$$FR_n = E_r \cdot FR'$$

= fraction of trapped population who could be rescued in favorable weather.

9. Given that adverse weather could preclude rescue for some trapped people,

FP_w = fraction of population subject to adverse weather, and

P_w = probability of occurrence of adverse weather. Then,

$$K_4 = FP_w \cdot P_w$$

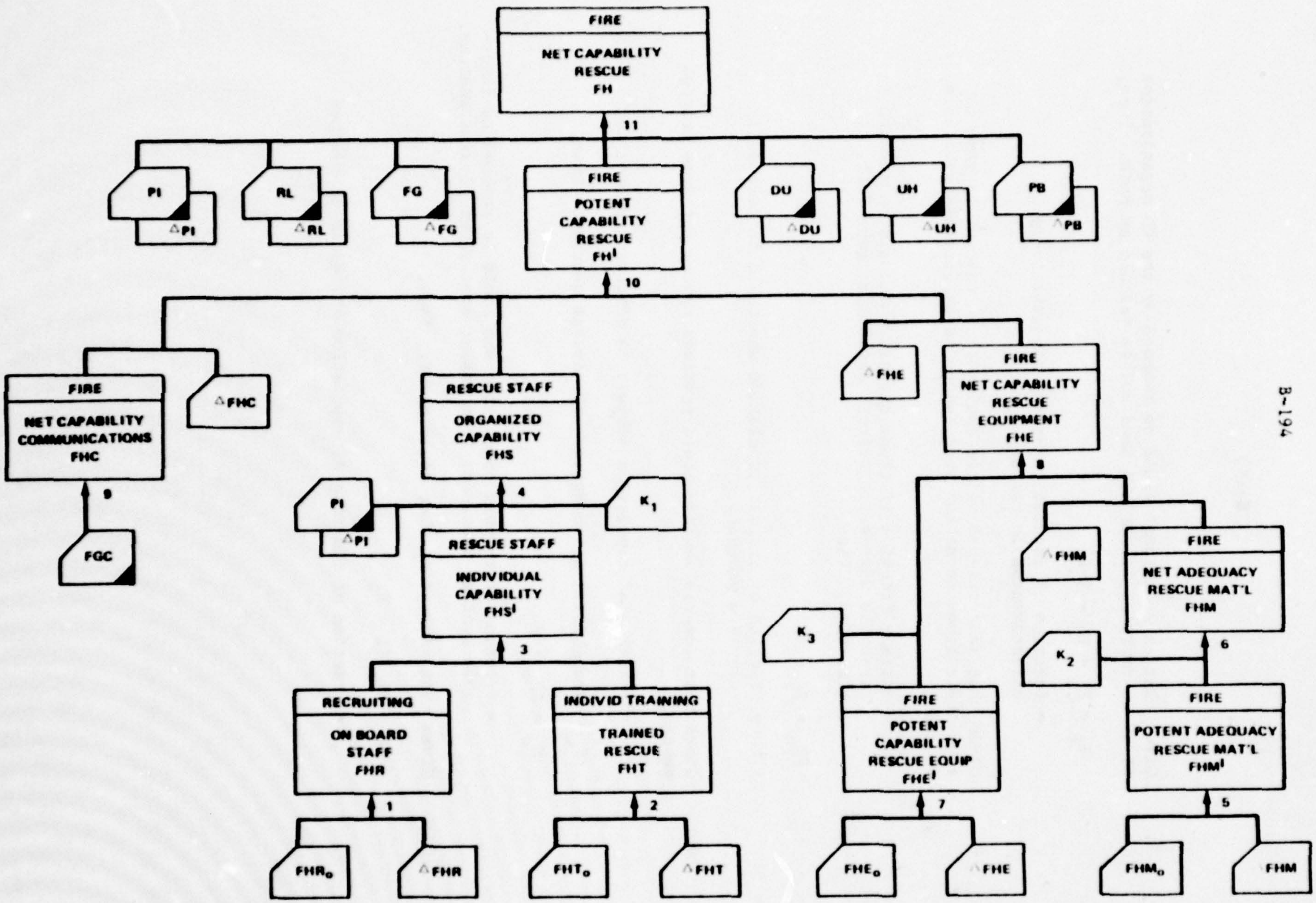
= fraction of trapped population who could be rescued in favorable weather precluded from rescue because of adverse weather.

10. Given that adverse weather could occur. Then,

$$FR = FR_n (1 - K_4)$$

= fraction of the trapped population who could be rescued.

RESCUE CAPABILITY – ORGANIZED – FH



RESCUE CAPABILITY - ORGANIZED - FH

Concept

FH = net capability of the fire service to rescue trapped people in an organized operation directed by D&C and supported by other emergency services.

Operation: An organized rescue service, which is part of the fire service, uses heavy equipment and special as well as common tools to release people who are trapped by debris. Efforts of the rescue service are supported by other elements of the CD organization under the general direction of D&C.

Analysis:

1. Given a rescue service, an element of the fire service,

FHR_o = fraction of population having adequate rescue staff at start of program, and

ΔFHR = net additional fraction for whom rescue staff is recruited during program. Then,

$$FHR = FHR_o + \Delta FHR$$

= fraction of population having adequate rescue staff at program completion.

2. Given on-board rescue staff who should be trained in rescue after nuclear attack.

FHT_o = fraction of population having adequate rescue staff trained in rescue after attack effects at start of program, and

ΔFHT = net additional fraction for whom rescue staff is trained during program. Then,

$$FHT = FHT_o + \Delta FHT$$

= fraction of population having adequate rescue staff individually trained at program completion.

3. Given that some of the rescue staff may be lost because of turnover either before or after being trained. Then,

$FHS' = \text{Min } FHR : FHS$

= fraction of population having adequate individually trained rescue staff on board at program completion.

4. Given
(a) that service exercise can increase staff capability and
(b) that some of the rescue staff may be incapacitated by attack effects,

ΔPI = maximum change in rescue staff capability between
(a) not having any service exercise for training and
(b) having fully adequate organization exercise for training,

PI = net adequacy of service exercise for training, and

K_1 = fraction of rescue staff effective after attack effects. Then,

$FHS = K_1 \cdot FHS'\{1 - \Delta PI(1 - PI)\}$

= fraction of population having adequate trained rescue staff after attack.

5. Given that organized rescue requires materials,

FHM_o = fraction of population having adequate materials for rescue at start of program, and

ΔFHM = net additional fraction for whom materials are procured in program. Then,

$FHM' = FHM_o + \Delta FHM$

= fraction of population having adequate rescue materials at program completion.

6. Given that some rescue materials may be destroyed or rendered unavailable because of attack effects so that,

K_2 = fraction of rescue materials available for use after attack effects. Then,

$FHM = K_2 \cdot FHM'$

= fraction of population having adequate rescue materials after attack.

7. Given that organized rescue requires equipment,

FHE_o = fraction of population having adequate rescue equipment at start of program, and

ΔFHE = net additional fraction for whom equipment is procured during program. Then,

$$FHE' = FHE_o + \Delta FHE$$

= fraction of population having adequate rescue equipment at program completion.

8. Given
(a) that having materials (tools, fuel, etc.) can increase the capability of rescue equipment, and
(b) that some rescue equipment may be rendered inoperable or unavailable by attack effects,

ΔFHM = maximum change in rescue equipment capability between
(a) not having any rescue materials and
(b) having a fully adequate supply of rescue materials, and

K_3 = fraction of rescue equipment operable after attack effects. Then,

$$FHE = K_3 \cdot FHE'\{1 - \Delta FHM(1 - FHM)\}$$

= fraction of population having adequate rescue equipment after attack.

9. Given
(a) that rescue forces need communications and
(b) that rescue forces are part of the fire service,

$$FHC = FGC$$

= fraction of population having adequate communications for organized rescue after attack.

10. Given that
(a) rescue staff capability can be enhanced by equipment and communications and
(b) it would be limited by the lesser of them,

ΔFHC = maximum change in capability of rescue staff between
(a) not having communications and
(b) having fully adequate communications, and

ΔFHE = maximum change in capability of rescue staff between
(a) not having any rescue equipment capability and
(b) having fully adequate rescue equipment capability. Then,

$$FH' = FHS \cdot \mathrm{Min}\{1 - \Delta FHC(1 - FHC)\}:\{1 - \Delta FHE(1 - FHE)\}$$

= fraction of population having adequate capability for organized rescue after attack if rescue forces are fully supported.

11. Given that rescue forces should be supported,

ΔPI = maximum change in rescue capability of fire service between
(a) not having any exercise of the CD organization and
(b) having fully adequate organization exercise,

PI = net adequacy of organization exercises,

ΔRL = maximum change in rescue capability of fire service between
(a) not having any building debris clearance support by the resource service and
(b) having fully adequate resource service support

RL = net capability of resource service to clear building debris,

ΔFG = maximum change in rescue capability of fire service between
(a) not having any fire fighting support by the fire service and
(b) having fully adequate fire fighting support,

FG = net capability of fire service to suppress fires while rescue operations are being conducted,

ΔDU = maximum change in rescue capability of fire service between
(a) not having any D&C information support and
(b) having fully adequate D&C information support,

DU = net capability of D&C to supply system information to fire service,

ΔUH = maximum change in rescue capability of fire service between
(a) not having any self-help RADEF capability and
(b) having fully adequate self-help RADEF capability,

UH = net capability of fire service for self-help RADEF,

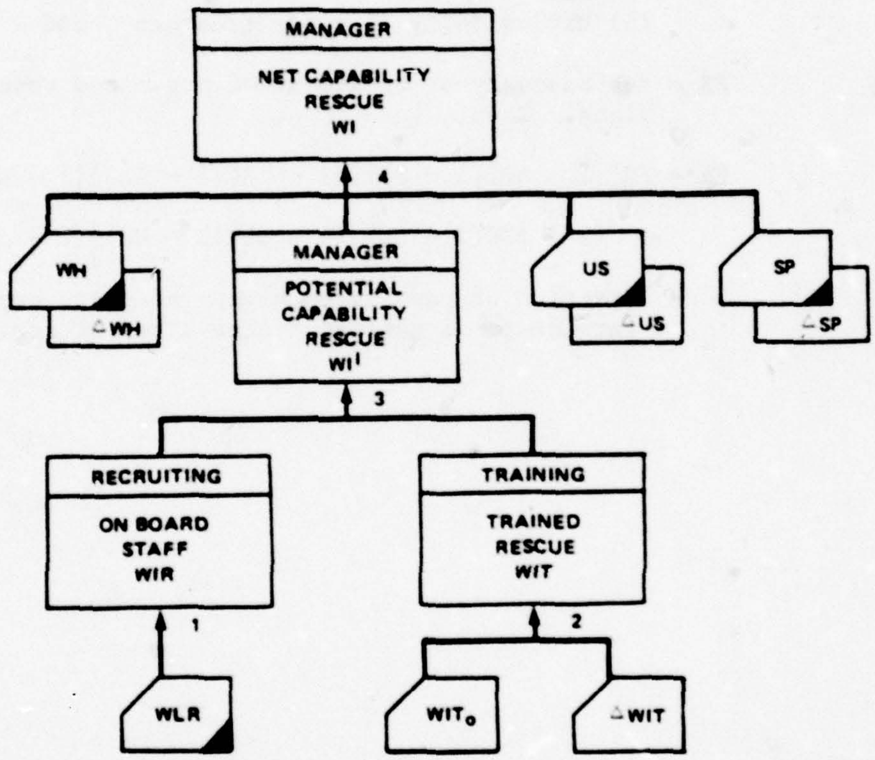
ΔPB = maximum change in rescue capability of fire service between
(a) not having organized rescue treated in operations plans and
(b) having fully adequate treatment, and

PB = net adequacy of treatment of organized rescue in operations plans. Then,

$$FH = FH'\{1 - \Delta PI(1 - PI)\}\{1 - \Delta RL(1 - RL)\}\{1 - \Delta FG(1 - FG)\}$$
$$\{1 - \Delta DU(1 - DU)\}\{1 - \Delta UH(1 - UH)\}\{1 - \Delta PB(1 - PB)\}$$

= fraction of population having adequate capability of fire service for organized rescue after attack.

RESCUE CAPABILITY – SHELTER MANAGER – WI



RESCUE CAPABILITY - SHELTER MANAGER - WI

Concept

WI = net capability of shelter managers to conduct shelter-based rescue activities using only the resources available in the shelters.

Operation: Many of those trapped could be released without the use of heavy equipment or special tools. This light rescue could be accomplished by shelter occupants led by the shelter manager.

Analysis:

1. Given shelter managers,

   WIR = WLR (Page B-137)

   = fraction of population having adequate shelter managers at program completion.

2. Given on-board shelter managers who should be trained in shelter-based rescue,

   WIT_o = fraction of population having shelter managers trained in shelter-based rescue at start of program, and

   ΔWIT = net additional fraction for whom managers are trained in rescue during program. Then,

   $WIT = WIT_o + \Delta WIT$

   = fraction of population having managers trained in shelter-based rescue by program completion.

3. Given that some managers would be lost because of turnover either before or after being trained. Then,

   WI' = Min WIR : WIT

   = fraction of population having managers capable of shelter-based rescue at program completion if fully supported.

4. Given
(a) that shelter-based fire suppression could increase rescue capability,
(b) that the managers might provide organization monitoring capability, and
(c) that system information from D&C could increase rescue capability,

ΔWH = maximum change in manager rescue capability between
(a) not having any shelter-based fire fighting capability, and
(b) having fully adequate shelter-based fire fighting capability,

WH = net capability of managers for shelter-based fire suppression,

ΔUS = maximum change in manager rescue capability between
(a) not having any shelter RADEF support and
(b) having fully adequate shelter RADEF support

US = net monitoring capability of CD organization personnel in shelters,

ΔSP = maximum change in manager rescue capability between
(a) not having any D&C information support and
(b) having fully adequate information support, and

SP = net capability of D&C to provide system information to shelters. Then,

$$WI = WI'\{1 - \Delta WH(1 - WH)\}\{1 - \Delta US(1 - US)\}\{1 - \Delta SP(1 - SP)\}$$

= fraction of population having adequate capability of shelter managers to conduct shelter-based rescue.

SECTION B.6

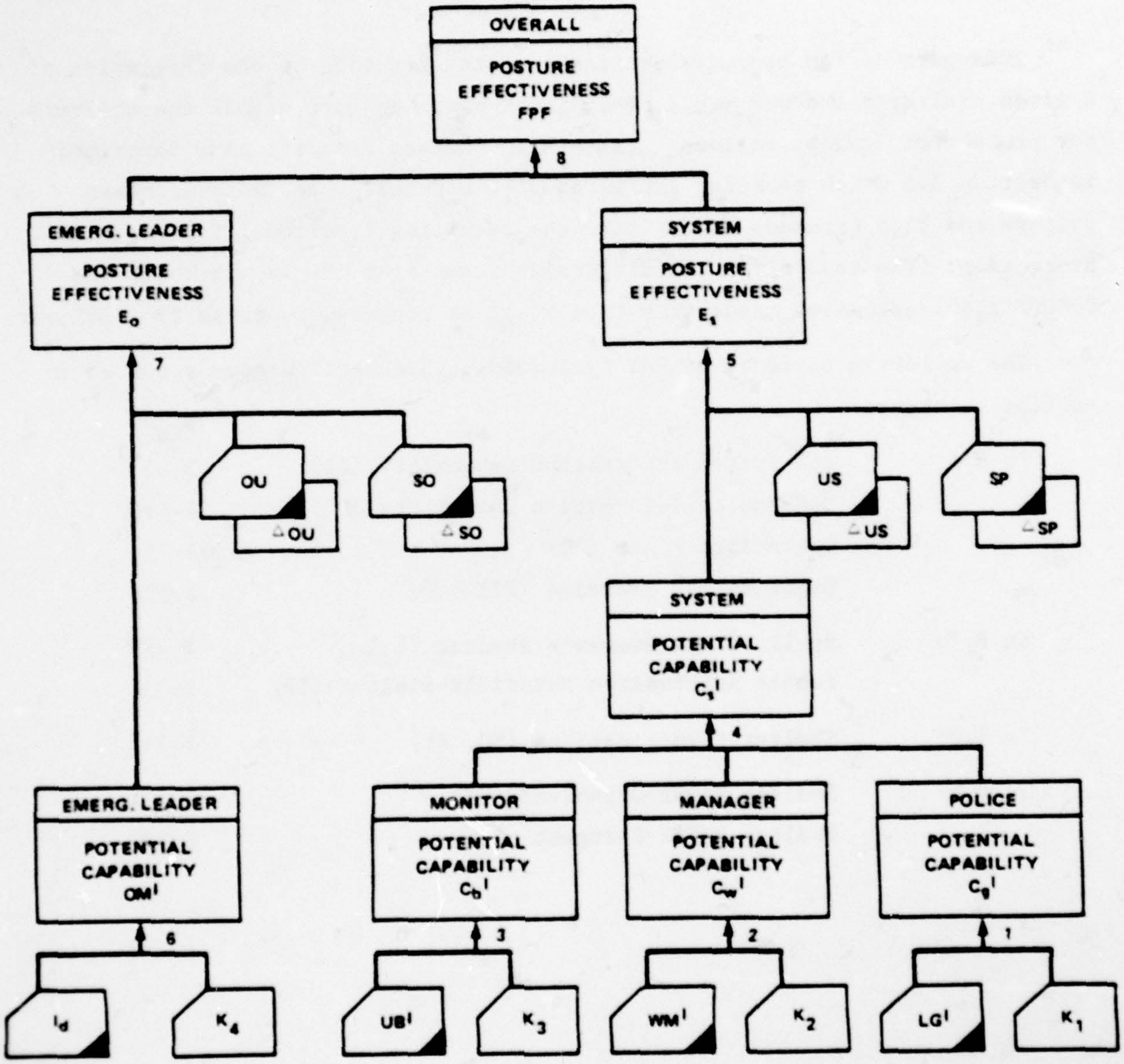
EFFECTIVENESS OF IMPROVING FALLOUT PROTECTION POSTURE (FPF)

This part of PAM produces estimates of the fraction of the population of a given shelter class who would be in an improved posture within the shelters for protection against fallout. In this it differs from the part described in Section B.3 which produces estimates of the fraction in improved blast posture and then proceeds to estimate the resulting fractional increase in protection. The reason for the difference stems from the way in which the POPDEF model estimates casualties from blast as compared to those from fallout.

The following elements of PAM included in this section have appeared in earlier sections:

		Page
In B.1:	D&C-System Information Capability (DZ)	B-63
	D&C-Public Information Capability (DS)	B-69
	Operations Plans (PB)	B-75
	Organization Exercise (PI)	B-97
In B.2:	Public Preparedness - Shelter (I_d)	B-129
	Public Information Materials-Shelter (ID)	B-131
In B.3:	Shelter Communications (SO, SP)	B-141
In B.4:	Shelter RADEF-Organized (US)	B-171
	Shelter RADEF-Emergent (OU)	B-177

EFFECTIVENESS OF IMPROVING FALLOUT PROTECTION POSTURE – FPF



IMPROVED FALLOUT POSTURE - FPF

Concept

FPF = net overall effectiveness of efforts to improve fallout posture; i.e., the fraction of the population in shelter class i who are placed in best posture to minimize radiation dose.

Operation: Some areas within a shelter will experience a lesser radiation intensity than others. When the occupants are arranged in these areas, the radiation dose they accumulate will be minimized. People can be placed in the preferred posture either on the basis of measurements of the actual radiation flux or on the basis of knowledge of which areas would likely experience the least radiation.

Analysis:

1. Given that policemen may be in shelters so that,

   LG' = fraction of population having policemen trained in improving fallout posture in shelters with them, and

   K_1 = relative capability of policemen trained in improving fallout posture to achieve improved posture. Then,

   $C'_g = K_1 \cdot LG'$

   = fraction of population who could be in improved fallout posture because of policemen if they were fully supported.

2. Given that managers may be in shelters so that,

   WM' = fraction of population having managers trained in improving fallout posture in shelters with them, and

   K_2 = relative capability of managers trained in improving fallout posture to achieve improved posture. Then,

   $C'_w = K_2 \cdot WM'$

   = fraction of population who could be in improved fallout posture because of managers if they were fully supported.

3. Given that monitors may be in the shelters so that,

UB' = fraction of population having monitors trained in improving fallout posture in shelters with them, and

K_3 = relative capability of monitors trained in improving fallout posture to achieve improved posture. Then,

$$C'_b = K_3 \cdot UB'$$

= fraction of population who could be in improved fallout posture because of monitors if they were fully supported.

4. Given that any individual could be in an improved fallout posture because of a policeman, a manager, or a monitor but need not have the assistance of more than one of them. Then,

$$C'_s = C'_g + C'_w + C'_b - C'_g C'_w - C'_g C'_b - C'_w C'_b + C'_g C'_w C'_b$$

= fraction of population who could be in improved fallout posture because of CD organization personnel if they were fully supported.

5. Given
(a) that, with CD personnel in shelter, there could be organization monitoring capability and
(b) that information from D&C could increase the effectiveness of efforts to improve posture,

ΔUS = maximum change in effectiveness of CD organization efforts to improve fallout posture between
(a) not having any organization monitoring capability and
(b) having fully adequate organization monitoring capability,

US = net organization capability for in-shelter monitoring,

ΔSP = maximum change in effectiveness of CD organization efforts to improve fallout posture between
(a) not having any guidance from D&C and
(b) having fully adequate guidance from D&C, and

SP = net capability of CD organization personnel to receive communications from D&C. Then,

$$E_s = C'_s\{1 - \Delta US(1 - US)\}\{1 - \Delta SP(1 - SP)\}$$

= fraction of population who would be in improved fallout posture because of CD organization personnel.

6. Given public information activities to prepare the public for shelter including improvement in fallout posture so that,

I_d = fraction of population who know about improving fallout posture, and

K_4 = relative capability of emergent leaders who know about improving fallout posture to achieve improved posture. Then,

$OM' = K_4 \cdot I_d$

= fraction of population who could be in improved fallout posture because of emergent leaders if they were fully supported.

7. Given
(a) that, without CD personnel in shelter, monitoring would be by emergent monitors, and
(b) that information from D&C could increase the effectiveness of emergent leaders.

ΔOU = maximum change in effectiveness of emergent leaders in achieving improved fallout posture between
(a) not having any monitoring capability and
(b) having fully adequate emergent monitoring capability,

OU = net capability of emergent monitors,

ΔSO = maximum change in effectiveness of emergent leaders in achieving improved fallout posture between
(a) not having any guidance from D&C and
(b) having fully adequate guidance from D&C, and

SO = net capability of emergent leaders to receive communications from D&C. Then,

$E_o = OM'\{1 - \Delta OU(1 - OU)\}\{1 - \Delta SO(1 - SO)\}$

= fraction of population who would be in improved fallout posture because of emergent leaders.

8. Given that any individual may be assisted by CD organization personnel or an emergent leader but need not be assisted by both,

$FPF = E_s + E_o - E_s E_o$

= fraction of population who would be in improved fallout posture.

SECTION B.7

FRACTION ABLE TO ACHIEVE SUCCESSFUL REMEDIAL MOVEMENT AFTER LEAVING SHELTER [F(X)R]

This part of PAM produces estimates of the fraction leaving shelter (either because of some adverse condition or because of ultimate emergence) who could move to a safer location than the shelter vicinity or benefit from other measures of equivalent effect. Only one formulation is given for the model; it applies to any of the conditions that would cause the movement. However, it is noted that the values of the inputs to the model would change with time after the attack and therefore, separate estimates are required for each different time at which the movement would occur.

The following elements of PAM included in this section have appeared in earlier sections:

		Page
In B.1:	D&C-System Information Capability (DZ)	B-63
	D&C-Public Information Capability (DS)	B-69
	Operations Plans (PB)	B-75
	Organization Exercise (PI)	B-97
In B.2:	Public Preparedness-Shelter (I_d)	B-129
	Public Information Materials-Shelter (ID)	B-131
In B.3:	Shelter Communications (SO, SP)	B-141
In B.4:	Shelter RADEF-Organized (US)	B-171
	Shelter RADEF-Emergent (OU)	B-177
	Self-Help RADEF (UH)	B-179

REMEDIAL MOVEMENT - F(X)R

Concept

F(X)R = fraction of those forced out of shelter who could achieve a successful remedial movement; i.e., who would move to a place where the injury they would suffer -- including that during the move -- would be substantially less than they would have suffered had they remained in the vicinity of the shelter.

Operation: Four situations in which remedial movement would be needed are considered:

1. Immediate: within the first day. The causes are:
   (a) FFR: forced out by fire
   (b) FRR: released from entrapment by immediate rescue

2. Early: from 1.5 to 2 days after attack. The causes are:
   (a) FWR: forced out by lack of water
   (b) FRR: released from entrapment by reentrant rescue

3. Delayed: from 3.5 to 6 days after attack; FVR: forced out by inadequate ventilation

4. Emergence: from 1 to 2 weeks after attack; FER: leaving shelter at the end of the expected stay

A remedial movement could be conducted in three alternative ways:

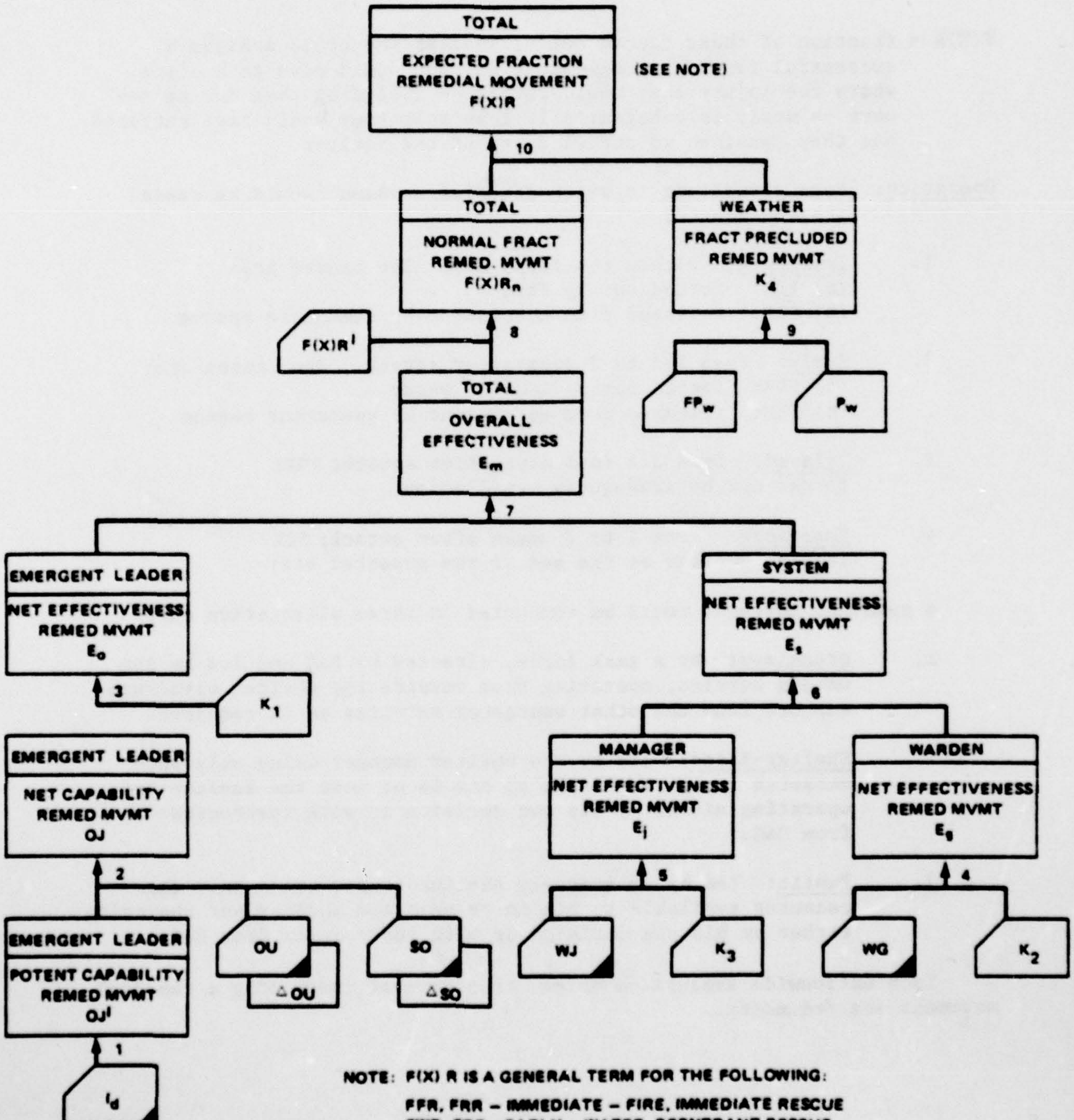
1. Organized: by a task force, directed by D&C and led by the warden service, operating from outside the shelter with such support from the other emergency services as is required.

2. Shelter-Based: led by the shelter manager using only such measures as are available to him in or near the shelter and operating either by his own decision or with instruction from D&C.

3. Public: led by an emergent shelter leader using only the measures available to him in or near the shelter and operating either by his own decision or with instruction from D&C.

In a nationwide evaluation these three ways of conducting a remedial movement are redundant.

REMEDIAL MOVEMENT – F(X)R



NOTE: F(X) R IS A GENERAL TERM FOR THE FOLLOWING:

FFR, FRR – IMMEDIATE – FIRE, IMMEDIATE RESCUE
FWR, FRR –EARLY – WATER, REENTRANT RESCUE
FVR – DELAYED – VENTILATION
FER – EMERGENCE – EMERGENCE FROM SHELTER

Analysis:

1. Given shelters with emergent leaders and a public preparedness information program for going to shelter, and

I_d = net effectiveness of the preparedness information program in educating emergent leaders in remedial movement. Then,

OJ' = fraction of the shelter class population with emergent leaders who would attempt remedial movement, given RADEF and D&C information support.

2. Given emergent leaders who would attempt remedial movement,

ΔOU = maximum change in emergent leader RM capability between (a) not having any emergent RADEF capability and (b) having fully adequate emergent RADEF capability,

OU = net RADEF capability of emergent monitors,

ΔSO = maximum change in emergent leader RM capability between (a) not having any D&C public information support and (b) having fully adequate D&C public information support,

SO = net adequacy of emergent leader capability to receive D&C instructions. Then,

$$OJ = OJ'\{1-\Delta OU(1-OU)\}\{1-\Delta SO(1-SO)\}$$

= fraction of shelter class population with emergent leader attempting remedial movement.

3. Given emergent leaders attempting remedial movement, and

K_1 = relative effectiveness of emergent leaders in achieving successful remedial movement. Then,

$$E_o = K_1 \cdot OJ$$

= fraction of shelter class population afforded successful remedial movement because of emergent leaders.

4. Given a CD organization net capability to achieve successful remedial movement - WG, and

K_2 = relative effectiveness of the CD organization in remedial movement. Then,

$E_g = K_2 \cdot WG$

= fraction of shelter class population who could achieve successful remedial movement because of organized effort.

5. Given a net capability of shelter managers attempting shelter-based remedial movement - WJ, and

K_3 = relative effectiveness of shelter managers in remedial movement. Then,

$E_j = K_3 \cdot WJ$

= fraction of shelter class population who could achieve successful remedial movement because of shelter managers.

6. Given that E_g and E_j represent the net effectiveness of redundant ways in which the CD organization can achieve remedial movement. Then,

$E_s = E_g + E_j - E_g E_j$

= fraction of shelter class population who could achieve successful remedial movement because of CD organization.

7. Given, similarly, that E_o and E_s represent the effectiveness of redundant ways of achieving remedial movement. Then,

$E_m = E_o + E_s - E_o E_s$

= fraction of shelter class population who could achieve successful remedial movement when feasible.

8. Given that for a number of reasons, it would not be feasible to achieve remedial movement for all who needed it,so that,

$F(X)R'$ = maximum fraction of the shelter class population who could be afforded remedial movement from cause (X) given favorable weather. Then,

$F(X)R_n = E_m \cdot F(X)R'$

= net fraction of shelter class population who could be afforded remedial movement because of cause (X) in favorable weather.

9. Given that adverse weather could occur when remedial movement was needed,

FP_w = fraction of shelter class population possibly subject to adverse weather, and

P_w = probability of occurrence of adverse weather. Then,

$K_4 = FP_w \cdot P_w$

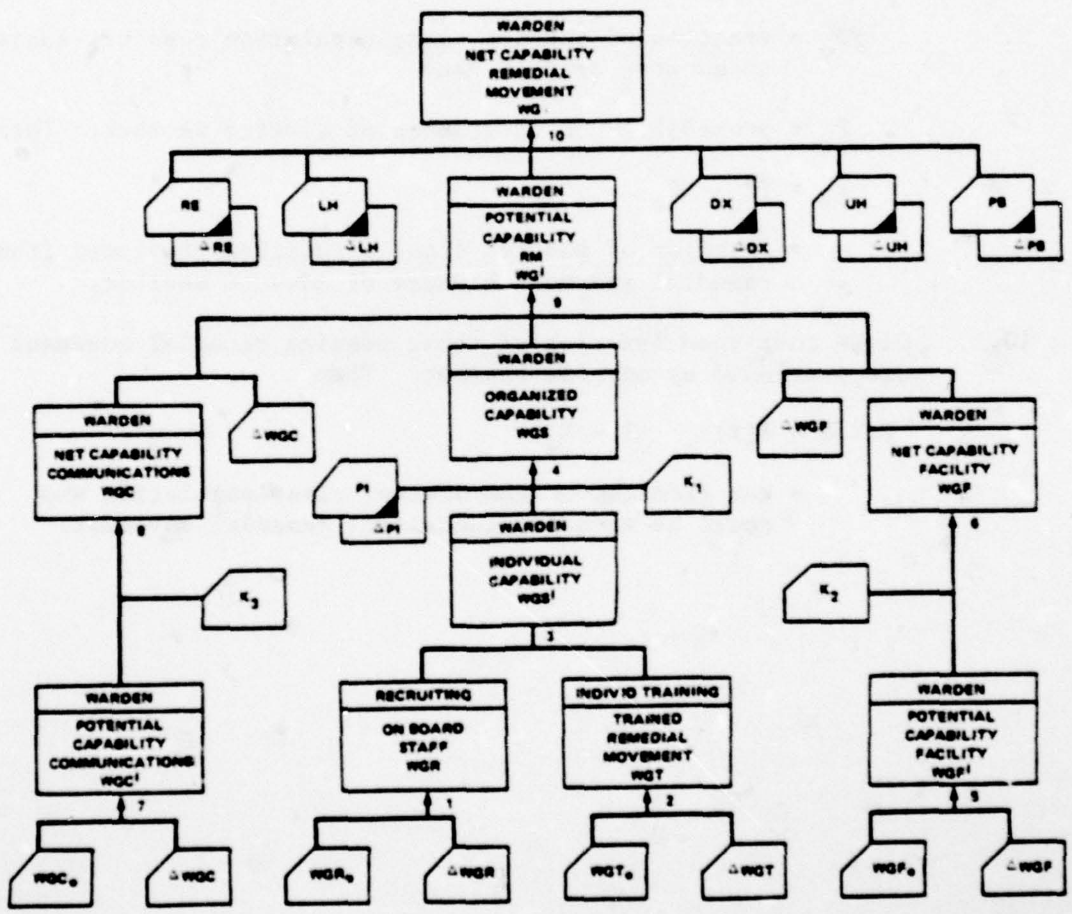
= fraction of shelter class population precluded from remedial movement because of adverse weather.

10. Given that some fraction of those needing remedial movement are precluded by adverse weather. Then,

$F(X)R = F(X)R_n \ (1 - K_4)$

= net fraction of the shelter class population who could be afforded successful remedial movement.

EFFECTIVENESS OF REMEDIAL MOVEMENT – ORGANIZED – WG



EFFECTIVENESS OF REMEDIAL MOVEMENT - ORGANIZED - WG

Concept

WG = net capability of the warden service to manage an organized remedial movement.

Operation: In the organized mode, a remedial movement is conducted from outside the shelter by a task force. The task force supplies transportation and guidance plus whatever other on-site support is required. D&C supplies information including operational directions and coordination instructions.

Analysis:

1. Given local CD organizations with an emergency service charged with responsibility for leading organized remedial movements and termed here "the warden service",

   WGR_o = fraction of population having sufficient warden service movement staff on board at start of program, and

   ΔWGR = net additional fraction for whom movement staff is recruited during program. Then,

   $WGR = WGR_o + \Delta WGR$

   = fraction of population having sufficient warden movement staff at program completion.

2. Given an on-board warden movement staff that preferably should be trained for organized remedial movement,

   WGT_o = fraction of population having sufficient trained warden service movement staff at start of program, and

   ΔWGT = net additional fraction for whom movement staff is trained during program. Then,

   $WGT = WGT_o + \Delta WGT$

   = fraction of population having sufficient warden staff trained in organized remedial movement at program completion.

3. Because of staff turnover, some of the movement staff may be lost before or after training. Then,

$WGS' = \text{Min } WGR : WGT$

= fraction of population with sufficient trained movement staff if adequately exercised.

4. Given that
(a) some of the movement staff would be rendered ineffective by attack effects and
(b) staff capability can be increased by service exercise,

K_1 = fractional survival of effective warden movement staff after attack effects,

ΔPI = maximum change in warden movement staff capability between (a) not having any organization exercise for training and (b) having fully adequate exercise for training, and

PI = net adequacy of organization exercise for training of the warden movement staff. Then,

$WGS = K_1 \cdot WGS'\{1-\Delta PI(1-PI)\}$

= fraction of population with sufficient effective, competent movement staff after attack.

5. Assuming that the movement staff operates from a central facility:

WGF_o = fraction of the population with adequate movement staff facilities at program start, and

ΔWGF = net additional fraction for whom facilities are procured in program. Then,

$WGF' = WGF_o + \Delta WGF$

= fraction of population with adequate movement staff facilities before attack.

6. Given an attack that could damage the facilities, and

K_2 = fractional survival of movement staff facilities after attack. Then,

$WGF = K_2 \cdot WGF'$

= fraction of population with adequate movement staff facilities after attack.

7. Assuming that the movement staff would have in-service communications,

WGC_o = fraction of population having adequate movement staff communications at program start, and

ΔWGC = net additional fraction for whom communications are procured in program. Then,

$WGC' = WGC_o + \Delta WGC$

= fraction of population with adequate movement staff communications before attack.

8. Given an attack that could damage communications, and

K_3 = fractional survival of movement staff communications after attack. Then,

$WGC = K_3 \cdot WGC'$

= fraction of population having adequate movement staff communications after attack.

9. Given that the purpose of movement staff facilities and communications is the increase of staff capabilities, and that it would be limited by the lesser of them,

ΔWGF = maximum change in organized remedial movement capability of movement staff between
(a) not having any facilities and
(b) having fully adequate facilities, and

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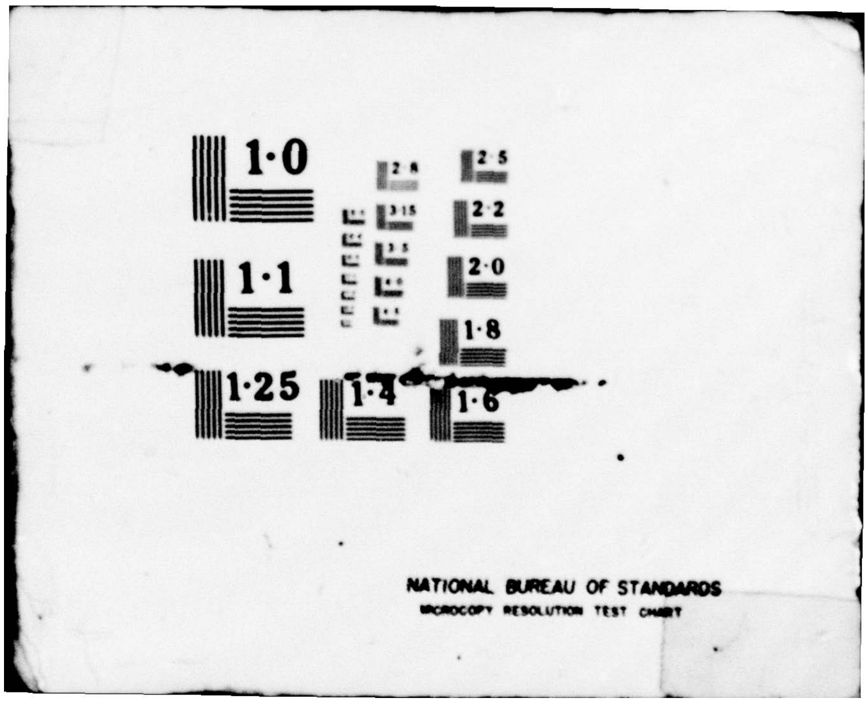
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NATIONAL BUREAU OF STANDARDS
MICROCOPY RESOLUTION TEST CHART

ΔWGC = maximum change in organized remedial movement capability of movement staff between
(a) not having any communications and
(b) having fully adequate communications. Then,

$$WG' = WGS \cdot \text{Min}\{1 - \Delta WGF(1 - WGF) : \{1 - \Delta WGC(1 - WGC)\}$$

= potential organized remedial movement capability of warden service after attack effects, if adequately supported by
(a) resource service transport capability
(b) police service traffic control capability
(c) D&C information
(d) self-help RADEF, and
(e) operations plans.

10. Given some level of needed support to the warden service in organized remedial movement,

ΔRE = maximum change in organized remedial movement capability of warden service between
(a) not having any transportation support by resource service and
(b) having fully adequate transport support,

RE = fraction of population having adequate transportation support after attack effects,

ΔLH = maximum change in organized remedial movement capability of warden service between
(a) not having any police service traffic control support and
(b) having fully adequate traffic control,

LH = fraction of population having adequate traffic control after attack,

ΔDX = maximum change in organized remedial movement capability of warden service between
(a) not having any D&C information support and
(b) having fully adequate D&C information support

DX = fraction of population with adequate D&C capability to inform system after attack,

ΔUH = maximum change in organized remedial movement capability of warden service between
(a) not having any self-help RADEF and
(b) having fully adequate self-help RADEF

UH = fraction of population having adequate self-help RADEF for the movement staff,

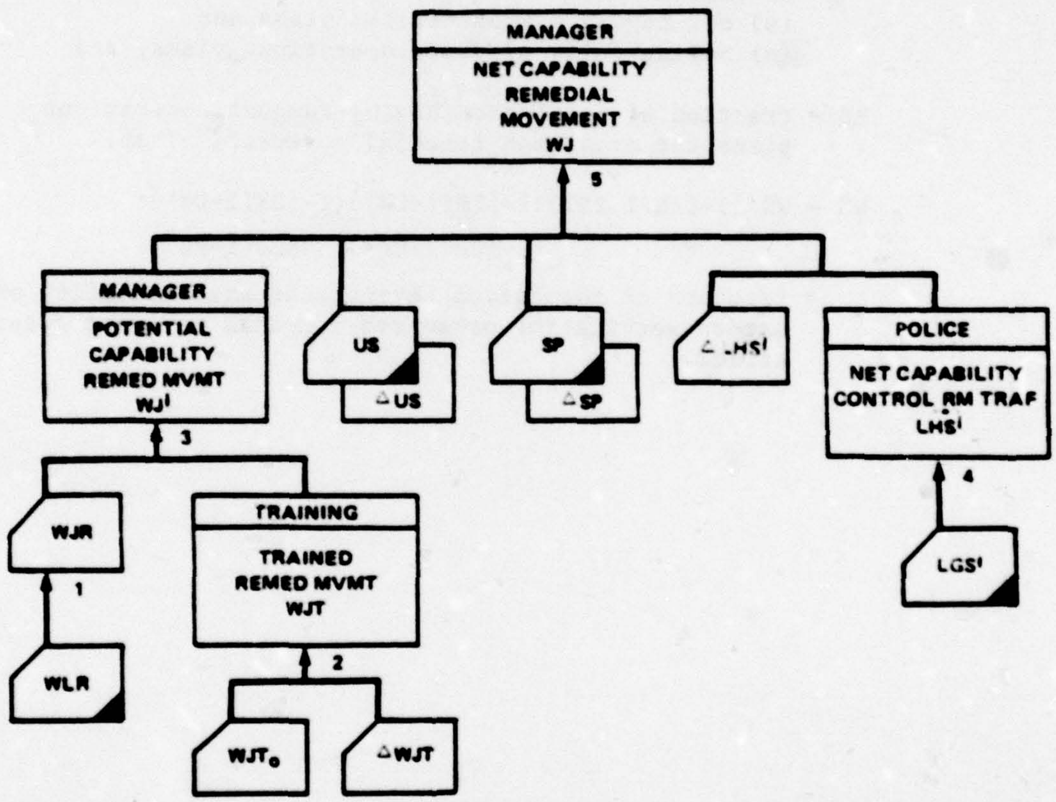
ΔPB = maximum change in organized remedial movement capability of warden service between
(a) not having any operations plans and
(b) having fully adequate operations plans, and

PB = fraction of population having adequate operations plans for organized remedial movement. Then,

$$WG = WG'\{1-\Delta RE(1-RE)\}\{1-\Delta LH(1-LH)\}\{1-\Delta DX(1-DX)\}\{1-\Delta UH(1-UH)\}\{1-\Delta PB(1-PB)\}$$

= fraction of population having adequate capability of warden service for organized remedial movement after attack.

EFFECTIVENESS OF REMEDIAL MOVEMENT SHELTER MANAGER – WJ



EFFECTIVENESS OF REMEDIAL MOVEMENT - SHELTER MANAGER - WJ

Concept

WJ = net capability of shelter managers to achieve successful shelter-based remedial movement.

Operation: A shelter manager may, upon his own decision or upon guidance from D&C, lead the people out of shelter to a place where the hazard is less. He would be supported by traffic control policemen who were in the shelters and by guidance from D&C.

Analysis:

1. Given shelter managers so that,

   WJR = WLR (Page B-137)

   = fraction of population with adequate shelter managers at program completion.

2. Given that managers should be trained in remedial movement,

   WJT_o = fraction of population having adequate trained managers at start of program, and

   ΔWJT = net additional fraction for whom managers are trained during program. Then,

   $WJT = WJT_o + \Delta WJT$

   = fraction of population with shelter managers trained in remedial movement by program completion.

3. Given that some managers will be lost because of turnover either before or after being trained, then,

   WJ' = Min WJR : WJT

   = fraction of population having adequate trained managers at program completion.

4. Given traffic policemen, trained in remedial movement, in shelters so that,

LHS' = LGS' (Page B-134)

= fraction of population having policemen trained in remedial movement in shelters with them.

5. Given that the remedial movement capability of managers can be increased by monitoring, D&C guidance, and police support,

ΔUS = maximum change in manager remedial movement capability between
(a) not having any shelter RADEF support and
(b) having fully adequate shelter RADEF support,

US = net monitoring capability of CD organization personnel,

ΔSP = maximum change in manager remedial movement capability between
(a) not having any D&C information support and
(b) having fully adequate D&C information support,

SP = net capability of manager to receive communications from D&C, and

ΔLHS' = maximum change in manager remedial movement capability between
(a) not having any police support and
(b) having fully adequate police support. Then,

$$WJ = WJ'\{1 - \Delta US(1 - US)\}\{1 - \Delta SP(1 - SP)\}\{1 - \Delta LHS'(1 - LHS')\}$$

= net capability of shelter managers to achieve successful shelter-based remedial movement.

POLICE - CONTROL REMEDIAL MOVEMENT - LH

Concept

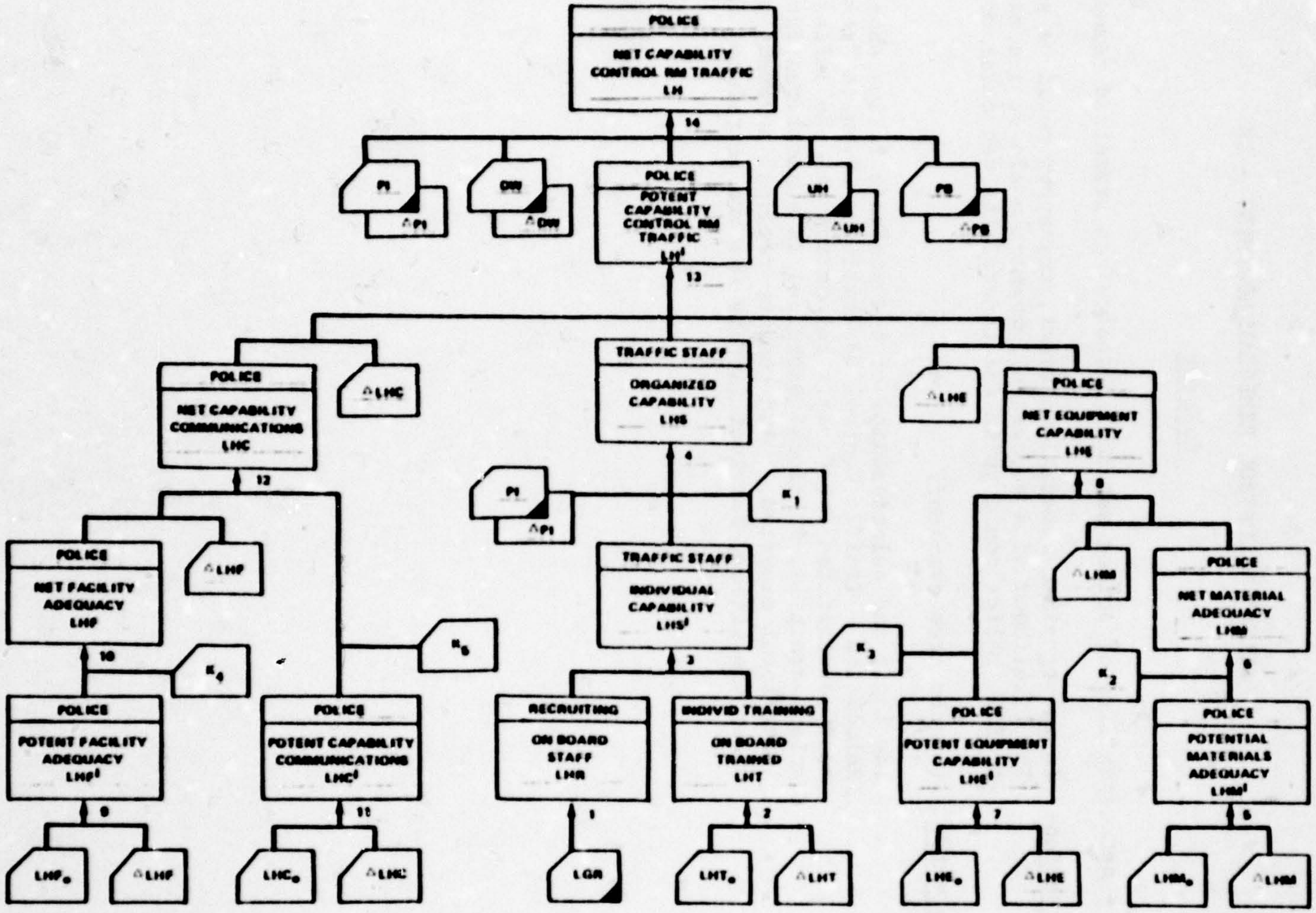
LH = net capability of police service to control an organized remedial movement.

Operation: In an organized remedial movement, transport would be supplied. The likelihood of a successful movement would be increased if traffic police could guide and control the vehicular movement.

Analysis: (System tree overleaf)

The logic and relationships of the analysis follow those of Crisis Relocation - Traffic Control Capability - LF, with "remedial movement" substituted for "crisis relocation" in the definitions. In relationship 14, PI (local exercise) is substituted for NI (joint State/local exercise). And because remedial movement would occur after the attack, survival factors (K) are introduced throughout.

POLICE - CONTROL REMEDIAL MOVEMENT - LH



Appendix C

METHOD OF ESTIMATING EFFECTIVE EXIT TIMES BECAUSE OF LACK OF WATER OR ADEQUATE VENTILATION

Appendix C

METHOD OF ESTIMATING EFFECTIVE EXIT TIMES BECAUSE OF LACK OF WATER OR ADEQUATE VENTILATION

CONTENTS

Appendix C

METHOD OF ESTIMATING EFFECTIVE EXIT TIMES BECAUSE OF LACK OF WATER OR ADEQUATE VENTILATION

General

People may be forced to leave protective shelter after a limited period of occupancy because of lack of drinking water and/or insufficient ventilation to maintain a habitable shelter environment. These problems are interrelated since the primary physiological mechanism for dissipating metabolic heat in a warm or hot environment is through the evaporation of sweat. Using the amount of dehydration as an index of shelter habitability has been suggested by Donald A. Bettge and has been used in internal DCPA case studies. The method to be presented in this appendix is an extension of the previous work, and accounts for the climatological variations throughout the United States.

Dehydration Criteria

Table C-1 is taken from Reference 1*. It describes the general physiological effects of dehydration, as measured by percent of body weight loss. It is necessary to choose one or more conditions in this table as the criterion for abandonment of shelter. One approach would be to recognize that some segments of the typical shelter population are more vulnerable to heat stress than others or are less able to tolerate the symptoms of dehydration. Thus, one might estimate the fraction of the population represented by these segments and assume that this fraction leaves the shelter environment earlier than the remainder and with less dehydration at the time of leaving. The practical difficulty with this approach is that one finds that the most vulnerable segments of the shelter population are the dependent segments: infants, the elderly, and women. It is difficult to believe that this group would emerge on their own.

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* References are cited at the end of this Appendix.

Table C-1

DEHYDRATION

DEHYDRATION WEIGHT LOSS - % INITIAL WEIGHT	
0 (Normal Weight)	
	Thirst
2	Stronger thirst, vague discomfort and sense of oppression, loss of appetite
	Increasing hemoconcentration
4	Economy of movement
	Lagging pace, flushed skin, impatience; in some, weariness and sleepiness, apathy; nausea, emotional instability
6	Tingling in arms, hands, and feet; heat oppression, stumbling, headache; fit men suffer heat exhaustion; increases in body temperature, pulse rate and respiratory rate
	Labored breathing, dizziness, cyanosis
8	Indistinct speech
	Increasing weakness, mental confusion
10	Spastic muscles; positive Romberg sign (inability to balance with eyes closed); general incapacity
	Delirium and wakefulness; swollen tongue
	Circulatory insufficiency; marked hemoconcentration and decreased blood volume; failing renal function
	Shriveled skin; inability to swallow
15	Dim vision
	Sunken eyes; painful urination
	Deafness; numb skin; shriveled tongue
	Stiffened eyelids
	Cracked skin; cessation of urine formation
20	Bare survival limit
	Death

Another approach would be to assume that all members of the shelter group emerge at the same time, including fit persons, when a substantial fraction of the group have suffered difficulties or have become casualties. This is the approach taken here. The question remains as to the level of dehydration to assume as the point of shelter exit. This level should not be chosen too low, since the group is leaving the shelter to enter a hazardous radiological environment. (If the area outside the shelter is not hazardous, there is no reason to consider remaining in the shelter.) The assumption used here is that an average 6 percent dehydration is the exit criterion. For calculational purposes, it is further assumed that the average person weighs 150 pounds (68 kilograms). Hence, 6 percent dehydration will be represented by a loss of 9 pounds (4.1 kilograms) of water from the average person.

Rates of Water Loss

The daily (or hourly) water loss is sharply dependent on whether sweating occurs or not. If sweating does not occur, water loss is limited to that in urine, respiration and feces primarily. Most of the loss is in urine. Assuming normal water intake, the urine loss is about 3 pounds (1.4 kilograms) per day under non-sweating conditions, according to Reference 2. The other losses account for an additional pound per day. Thus, when water is freely available, the demand in the non-sweating environment would be 4 pounds (about 2 quarts or liters per day). If drinking water is unavailable or sharply limited, there seems to be no reduction in urine flow until a deficit of 7 percent of body weight is exceeded, so long as sweating does not occur. Since this level of dehydration is beyond that assumed for shelter exit calculations, we will assume a loss of 4 pounds (1.8 kilograms) per day in the non-sweating environment. When sweat production occurs, the quantity of urine produced diminishes and its concentration increases. On the average,

the urinary loss may be halved. We will assume a reduction from 3 pounds per day to 2 pounds per day. Thus, in a sweating environment, the water loss, in addition to the sweat rate, will be assumed to be 3 pounds (1.4 kilograms) per day.

The water loss due to sweating is best measured by the predicted four-hour sweat rate (P4SR) data (Reference 2, page 60). Figure C-1 is based on Reference 3, which exhibits relationships of the four-hour sweat rate in liters to the saturated air temperature for various rates of air movement. The lowest rate of air movement (10 feet per minute), which is commonly equated to still air, is appropriate for the shelter situation. Three sets of curves are given in Reference 3 for 50, 75, and 100 kilogram-calories of metabolic heat per square meter of body surface per hour. According to Reference 1, the human body surface approximates 2 square meters. Hence, the three sets represent metabolic rates of 100, 150, and 200 kilogram-calories per hour. Since a kilogram-calorie is equivalent to approximately 4 British Thermal Units (BTU), the sets of curves are also appropriate to 400, 600, and 800 BTU per hour respectively.

For this analysis, we will use a metabolic output of 480 BTU per hour, the level measured by Heiskell[4] for normal shelter living. Further, we will use pounds of water lost in lieu of liters, on the basis that a liter of water weighs 2.21 pounds. The resulting relationship of saturated air temperature in degrees Fahrenheit to water loss in pounds is shown in Figure C-1. It will be noted that sweating begins at 82°F for these conditions and the four-hour sweat loss exceeds 5 pounds at 92°F.

The saturated air temperature is but one point on the Effective Temperature line. Other points represent lower relative humidities and higher dry bulb temperatures. From data presented in Reference 2, it is concluded that the

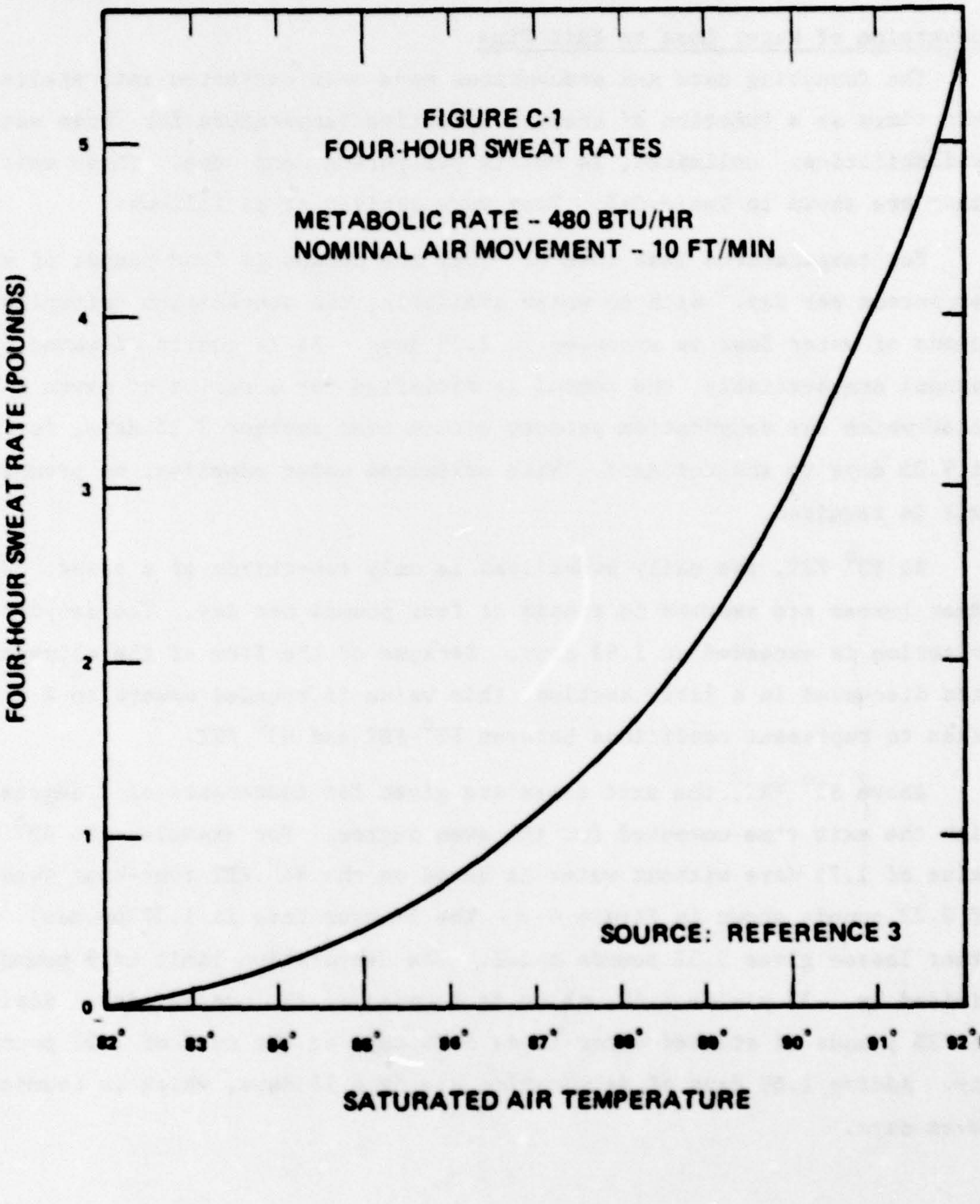

FIGURE C-1
FOUR-HOUR SWEAT RATES

saturated air temperature curve of Figure C-1 can be used with Effective Temperature data, with the no-sweat condition applying to all Effective Temperatures below 82^{o}F.

Conversion of Water Loss to Exit Time

The foregoing data and assumptions have been converted into shelter exit times as a function of shelter Effective Temperature for three water availabilities: unlimited, 14 quarts per person, and none. These exit times are shown in Table C-2. They were arrived at as follows:

For temperatures less than 82^{o} FET, the demand is four pounds of water per person per day. With no water available, the dehydration criterion of 9 pounds of water loss is exceeded in 2.25 days. If 14 quarts of water (28 pounds) are available, the demand is satisfied for a period of seven days, after which the dehydration process occurs over another 2.25 days, for a total of 9.25 days to shelter exit. With unlimited water supplies, no premature exit is required.

At 83^{o} FET, the daily sweat loss is only two-thirds of a pound. The other losses are assumed to remain at four pounds per day. The dehydration criterion is exceeded at 1.93 days. Because of the form of the climatological data discussed in a later section, this value is rounded upward to 2 days and taken to represent conditions between 82^{o} FET and 83^{o} FET.

Above 83^{o} FET, the exit times are given for increments of 2 degrees, with the exit time computed for the even degree. For example, the 83^{o} to 85^{o} value of 1.75 days without water is based on the 84^{o} FET four-hour sweat rate of 0.22 pounds shown in Figure C- 1. The 24-hour rate is 1.32 pounds. Adding other losses gives 5.32 pounds total. The dehydration limit of 9 pounds divided by 5.32 yields 1.69, which is rounded to the quarter day. Similarly, the 28 pounds of stocked water lasts 5.26 days at the rate of 5.32 pounds per day. Adding 1.69 days of dehydration yields 6.95 days, which is rounded to seven days.

Table C-2

SHELTER EXIT TIMES (Days)

Effective Temperature	Water Availability: None	14 Qts	Unlimited
Less Than 82°F	2.25	9.25	Indef.
82°F - 83°F	2.0	8.0	Indef.
83°F - 85°F	1.75	7.0	Indef.
85°F - 87°F	1.25	5.0	Indef.
87°F - 89°F	0.75	3.0	Indef.
89°F - 91°F	0.50	2.0	Indef.
Greater Than 91°F	0.25	1.0	1.0

The shelter exit times shown in the last line of Table C-2 ostensibly cover all Effective Temperatures above 91°F. As will be shown in the next section, the likelihood of occurrence of these temperatures is very low and mainly limited to certain regions of the Gulf Coast. Hence, the exit times shown for no water and 14 quarts of water are based on 92°F. The 1-day exit time for unlimited water supply is based on data analysis in Reference 2 that indicates that above 91° FET heat stress is severe in many people as evidenced by an uncontrollable rise in body temperature. In these circumstances, dehydration is no longer controlling.

It should be noted that the validity of the exit times shown in Table C-2 depends not only on the assumption that the physiological and psychological effects of dehydration can be used to measure shelter habitability but also that the predicted four-hour sweat rate (P4SR) can be used to measure increased water loss at high Effective Temperatures. The P4SR is a predicted average for acclimatized, fit young men. People vary widely in their ability to perspire -- including acclimatized, fit young men. Our assumption is that the P4SR describes the average sweat loss for the population as a whole.

Likelihood of Shelter Effective Temperatures

Measurements made during shelter occupancy tests demonstrate that, after real or simulated occupants begin giving off metabolic heat in a fully-loaded shelter (10 square feet of floor space per occupant), the shelter Effective Temperature rises in a matter of a few hours to a maximum that is dependent on the temperature and humidity of the outside air and on the ventilation rate. The shelter temperature varies diurnally and with the daily average outside temperature but these variations are minor when Effective Temperatures above 82°F are attained. Thus, the occurrence of high shelter temperatures is very much a seasonal phenomenon and the percentage of the year during which a habitable environment prevails is related to the climate at the location of the shelter.

Shelter Effective Temperatures have been derived from climatological data by Baschiere and Lokmanhekim[5] for 91 weather stations throughout the country, using an adiabatic model of the shelter environment. Results for a typical station are shown in Figure C-2. Curves of Effective Temperature are given as a function of ventilation rate and "ventilation adequacy factor" -- actually, the fraction of a ten-year weather history during which the stated ventilation rate would limit the Effective Temperature in the shelter to less than the stated value. For example, in Wichita Falls, Texas, Figure C-2 shows that a ventilation rate of 15 cfm per person (for a shelter loaded at 10 square feet per person) would maintain the shelter Effective Temperature at 76°F or less (the lowest curve) 59 percent of the time, according to the adiabatic model. Comparison of this model with test data indicates that it consistently overestimates the maximum Effective Temperature by about 1 degree Fahrenheit. Hence, calculated data of the type shown in Figure C-2 can be used to define the likelihood of shelter Effective Temperatures if the values shown are reduced by one degree.

Natural Ventilation Rate

If it is assumed that electric power would be interrupted by an attack, shelters would need to depend on natural ventilation unless ventilation devices were stocked. Hence, one condition of shelter habitability would be related to lack of ventilator stocking, in which natural ventilation rates would prevail. High Effective Temperatures are expected only in basement areas since available data suggest that ventilation through windows in above ground parts of buildings would be adequate. The calculated data of Reference 5 are appropriate to basement areas.

Natural ventilation rates in basement shelters have been measured by Libovicz et al[6] and by a research team at Pennsylvania State University.[7,8]

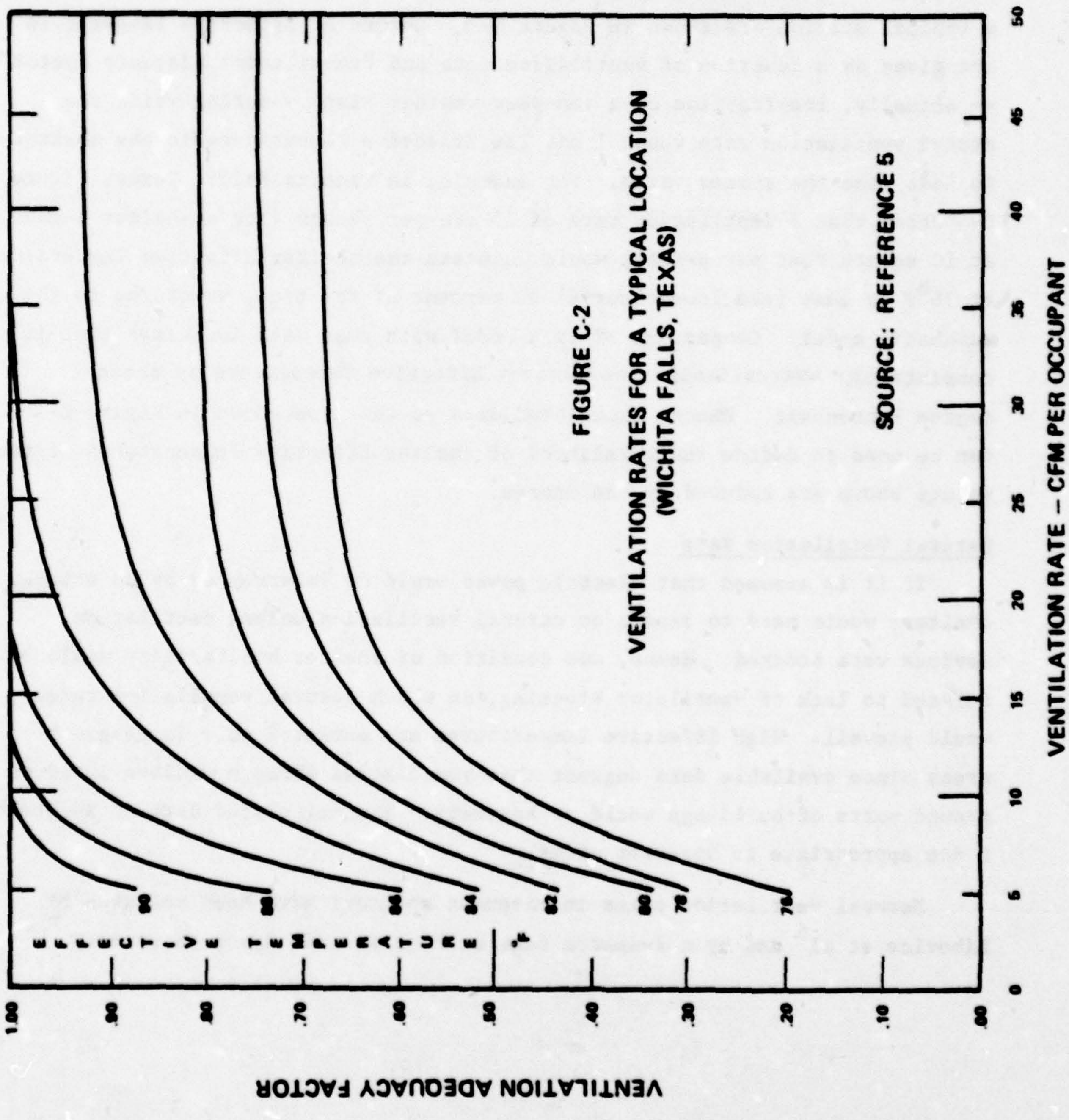

FIGURE C-2

VENTILATION RATES FOR A TYPICAL LOCATION (WICHITA FALLS, TEXAS)

SOURCE: REFERENCE 5

In the first instance, several tests in a Milwaukee basement shelter yielded natural ventilation rates of from 3.9 to 6.2 cfm, with an average of 5.1 cfm. In tests in the basement of a 4-story building at PSU, observed rates ranged from 6 to 19 cfm. Later experiments in an 8-story building gave rates ranging from 3.5 cfm to 77.0 cfm. Picking the lowest observed natural ventilation rate would maximize the need for and effectiveness of a program of stocking ventilation. On the other hand, high ventilation rates were observed only when stairwells in 4- to 8-story buildings were used to maximum effect; a condition not likely to occur widely. Our judgment is that 5 cfm per person, the lowest ventilation rate for which shelter ET calculations are available, is a reasonable choice.

Ventilation With Stocked Ventilators

It will be assumed for this calculation that when vent kits are procured for basement shelters they will be distributed in such a way that a ventilation rate will be provided so that 82° FET (the no-sweat limit) is exceeded only 10 percent of the time (90 percent ventilation adequacy factor), except that in no case will more than 30 cfm per person be provided.

Selection of Temperature Distributions

With the foregoing discussion in mind, the data for the 91 stations in reference 5 were reviewed. Stations with similar climatology were grouped together, with special emphasis on the ventilation rate required to achieve a 90 percent probability of not exceeding 82° FET and on the probability of not exceeding 82° FET at the 5 cfm per person rate. Eleven stations were chosen as representative of the entire set of data. For these stations, cross-curves were plotted and the cumulative probability distributions decomposed above 82° FET to match the ranges used in Table C-2. The results are shown in Table C-3. The upper part of the table reflects the condition for 5 cfm per

Table C-3

PROBABILITY OF EXPERIENCING VARIOUS SHELTER EFFECTIVE TEMPERATURES

		Effective Temperature (^{o}F)						
		Less Than 82^{o}	82^{o} - 83^{o}	83^{o} - 85^{o}	85^{o} - 87^{o}	87^{o} - 89^{o}	89^{o} - 91^{o}	Greater Than 91^{o}
		Natural Ventilation						
A	Portland, OR	84%	4%	5%	3%	2%	2%	-
B	Portland, ME	79%	4%	8%	5%	2%	2%	-
C	Providence, RI	70%	6%	10%	7%	4%	2%	1%
D	Long Beach, CA	62%	10%	13%	7%	4%	2%	2%
E	Washington, DC	58%	4%	10%	11%	10%	5%	2%
F	Charlotte, NC	50%	5%	11%	13%	11%	10%	-
G	Montgomery, AL	39%	5%	10%	12%	21%	13%	-
H	Baton Rouge, LA	30%	6%	10%	15%	17%	22%	-
I	Miami, FL	10%	4%	26%	30%	30%	-	-
J	Dallas, TX	38%	4%	10%	16%	18%	14%	-
K	Galveston, TX	25%	4%	4%	15%	18%	28%	6%
		With Ventilation						
A	Portland, OR	90%	4%	3%	2%	1%	-	-
B	Portland, ME	90%	3%	3%	2%	2%	-	-
C	Providence, RI	90%	3%	3%	2%	2%	-	-
D	Long Beach, CA	90%	4%	4%	2%	-	-	-
E	Washington, DC	90%	2%	6%	2%	-	-	-
F	Charlotte, NC	90%	4%	5%	1%	-	-	-
G	Montgomery, AL	90%	4%	5%	1%	-	-	-
H	Baton Rouge, LA	90%	5%	4%	1%	-	-	-
I	Miami, FL	90%	7%	3%	-	-	-	-
J	Dallas, TX	88%	5%	6%	1%	-	-	-
K	Galveston, TX	80%	9%	8%	3%	-	-	-

person. The lower part of the table reflects the condition of variable ventilation rates needed to provide a 90 percent reliability of not exceeding 82° FET with the exception of the last two groups where the limitation of 30 cfm per person applies.

It will be noted that Effective Temperatures greater than 91°F are encountered only in the natural ventilation case and then only a few percent of the time, the worst case being Galveston, Texas, at 6 percent. Since this extreme condition is the only circumstance where early shelter exit is predicted despite an unlimited water supply (Table C-2), the unlimited water supply case will be dropped from further consideration. Availability of 2 to 3 gallons per person per day will permit an indefinite stay at natural ventilation rates for all practical purposes.

Four combinations remain between Tables C-2 and C-3: no water and no ventilators; water stocked but no ventilators; ventilators stocked but no water; and both water and ventilators stocked. For each of these cases, the appropriate exit times of Table C-2 can be associated with the probabilities in Table C-3. The results are shown in Tables C-4 and C-5. Moreover, each climate group can be associated with specific geography, albeit with some arbitrariness at boundaries. In most cases, whole states will be associated with a particular climate group. Providence, Rhode Island, for example, is representative of 20 out of 91 stations across the country. Miami, Florida, on the other hand, is representative only of south Florida. Florida and a number of other States will need to be partitioned along county boundaries among two or more climate groups. However, the State and county designators associated with each grid square in the TENOS model could be used to direct the computer to a specific look-up table where the appropriate probabilities of early exit times would be found. The exit times would be used to generate effective protection factors for each shelter class in the grid and the resulting fallout casualties would be weighted by the probabilities of the exit times.

Table C-4

PROBABILITY OF SHELTER EXIT TIMES WITH NATURAL VENTILATION

CASE 1 - NO WATER

CLIMATE GROUP	2.25 days	2.0 days	1.75 days	1.25 days	0.75 days	0.5 days	0.25 days
A	84%	4%	5%	3%	2%	2%	-
B	79%	4%	8%	5%	2%	2%	-
C	70%	6%	10%	7%	4%	2%	1%
D	62%	10%	13%	7%	4%	2%	2%
E	58%	4%	10%	11%	10%	5%	2%
F	50%	5%	11%	13%	11%	10%	-
G	39%	5%	10%	12%	21%	13%	-
H	30%	6%	10%	15%	17%	22%	-
I	10%	4%	26%	30%	30%	-	-
J	38%	4%	10%	16%	18%	14%	-
K	25%	4%	4%	15%	18%	28%	6%

CASE 2 - WITH 14 QTS WATER/PERSON

	9.25 days	8.0 days	7.0 days	5.0 days	3.0 days	2.0 days	1.0 days
A	84%	4%	5%	3%	2%	2%	-
B	79%	4%	8%	5%	2%	2%	-
C	70%	6%	10%	7%	4%	2%	1%
D	62%	10%	13%	7%	4%	2%	2%
E	58%	4%	10%	11%	10%	5%	2%
F	50%	5%	11%	13%	11%	10%	-
G	39%	5%	10%	12%	21%	13%	-
H	30%	6%	10%	15%	17%	22%	-
I	10%	4%	26%	30%	30%	-	-
J	38%	4%	10%	16%	18%	14%	-
K	25%	4%	4%	15%	18%	28%	6%

Table C-5

PROBABILITY OF SHELTER EXIT TIMES WITH VENTILATOR KITS

CASE 3 - NO WATER

CLIMATE GROUP	2.25 days	2.0 days	1.75 days	1.25 days	0.75 days	0.5 days	0.25 days
A	90%	4%	3%	2%	1%	-	-
B	90%	3%	3%	2%	2%	-	-
C	90%	3%	3%	2%	2%	-	-
D	90%	4%	4%	2%	-	-	-
E	90%	2%	6%	2%	-	-	-
F	90%	4%	5%	1%	-	-	-
G	90%	4%	5%	1%	-	-	-
H	90%	5%	4%	1%	-	-	-
I	90%	7%	3%	-	-	-	-
J	88%	5%	6%	1%	-	-	-
K	80%	9%	8%	3%	-	-	-

CASE 4 - WITH 14 QTS WATER/PERSON

	9.25 days	8.0 days	7.0 days	5.0 days	3.0 days	2.0 days	1.0 days
A	90%	4%	3%	2%	1%	-	-
B	90%	3%	3%	2%	2%	-	-
C	90%	3%	3%	2%	2%	-	-
D	90%	4%	4%	2%	-	-	-
E	90%	2%	6%	2%	-	-	-
F	90%	4%	5%	1%	-	-	-
G	90%	4%	5%	1%	-	-	-
H	90%	5%	4%	1%	-	-	-
I	90%	7%	3%	-	-	-	-
J	88%	5%	6%	1%	-	-	-
K	80%	9%	8%	3%	-	-	-

Effective Exit Times

The foregoing procedure, while feasible, would be cumbersome even on the DCPA computer. For CD programs based on use of "best available shelter", there would usually be several basement shelter categories, each with its own rated protection factor against fallout radiation. For each rated protection factor, an average of five effective protection factors would need to be obtained, either analytically or from a look-up table, one for each exit time appropriate to the climate group associated with the grid square. The most accurate routine would carry these effective protection factors through the casualty computation for the grid square, multiplying each result by the product of the population sheltered and the probability of the exit time, and then summing to obtain the expected fatalities and casualties. To avoid this proliferation of calculations, an analysis was made to determine whether an "effective exit time" could be substituted for the probability distribution of exit times for a climate group.

An obvious candidate for use as an effective exit time is the "weighted average" obtained by multiplying each exit time by its probability of occurrence and summing the products. This procedure, however, would ignore the possibility that the casualty-producing significance of earlier exit times might increase rapidly. Moreover, the weighted average might conceal a sensitivity to the type of fallout threat, the rated protection factor, or other measures affecting the production of fallout casualties. Hence, calculations were carried out by hand to assess these sensitivities.

The procedure was essentially as described above. For each climate group and each water-ventilation combination (Tables C-4 and C-5), an effective protection factor was established for each exit time, which was then used to determine a "cookie-cutter" survival rate at a median lethal dose of 450 ERD. The results were multiplied by the appropriate probabilities

and the products summed to obtain an expected survival rate. The process was then reversed. The effective protection factor was determined that would produce this expected survival rate. Then, the exit time associated with this effective protection factor was determined. This was the desired "effective exit time" in that its use in lieu of the probability distribution would produce the same fatality rate as would the distribution itself.

Calculations were made for two different fallout environments: an all-surface-burst attack and a half-surface-burst attack. For each environment, calculations were made for rated protection factors of 50 and 500 in order to assess the sensitivity over a range of protection factors. Also, effective protection factors were derived for one- and five-hour fallout arrival times with and without remedial movement following shelter exit (See Reference 9 for a discussion of these variables). As expected, the resulting effective exit times were generally earlier than the weighted average of the distribution, indicating that the earliest exit times are relatively more significant in producing fatalities. On the other hand, the results were quite insensitive to the attack environment, the rated protection factor, and the fallout arrival time. There were, however, significant differences between the results assuming no remedial movement and those assuming four-hour remedial movement to an area of an order-of-magnitude less hazard.

The essential results are shown in Table C-6. It can be seen that the effective exit times with remedial movement are significantly earlier than those assuming no remedial movement. This does not mean that remedial movement is ineffective in reducing fallout casualties, since the effective protection factors in this case are near the rated protection factor. The result is caused by the need to skew the effective exit time more strongly toward the earliest exit time to match the production of fatalities.

Table C-6

EFFECTIVE EXIT TIMES

EXIT TIMES (Days)

CLIMATE GROUP	No Water; No Vent		Water; No Vent		Vent; No Water		Water; Vent	
	No Remed Movement	Remedial Movement	No Remed Movement	Remedial Movement	No Remed Movement	Remedial Movement	No Remed Movement	Remedial Movement
A	2.1	1.75	8.5	4.5	2.2	2.1	9.0	7.0
B	2.0	1.65	8.3	4.4	2.2	2.1	9.0	7.0
C	1.95	1.5	7.8	4.2	2.2	2.1	9.0	7.0
D	1.9	1.45	7.5	4.1	2.2	2.1	9.0	7.0
E	1.75	1.3	6.7	3.7	2.2	2.1	9.0	7.0
F	1.6	1.2	6.3	3.5	2.2	2.1	9.0	7.0
G	1.4	1.1	5.5	3.0	2.2	2.1	9.0	7.0
H	1.3	1.05	4.8	2.7	2.2	2.1	9.0	7.0
I	1.25	1.0	4.7	2.6	2.2	2.1	9.0	7.0
J	1.4	1.1	5.7	3.0	2.2	2.1	9.0	7.0
K	1.1	0.95	4.0	2.3	2.2	2.1	9.0	7.0

It should also be noted that the entries for the last two cases where ventilation is provided are identical for all climate groups. In effect, the provision of ventilation at the 90 percent adequacy factor (Table C-5) eliminates the effect of climate for all practical purposes. When basement shelters are naturally ventilated (first two sets of columns in Table C-6), the effective exit times differ by about a factor of two between the northernmost climate (group A) and the southernmost (group K).

Weighted Effective Exit Times

The findings that effective exit times for the ventilation kit cases are independent of climate group and vary by only a factor of two for the natural ventilation cases suggest that single effective exit times could be specified for each case that would be independent of climate. This would reduce the computational procedure to the same level as that used in Reference 9.

Since the effective exit times for the ventilation kit cases were found to be essentially independent of climate, the remaining problem is to properly weight the exit times shown in Table C-6 for the natural ventilation cases. These should be weighted by the fraction of the population in each climate group. A calculation was made of the distribution of population among the climate groups with the results shown in Table C-7. It can be seen that most of the population is accounted for by Climate Groups C, E, and F. The resulting weighted effective exit times lie between the effective exit times for Groups C and E and are 1.87 days, 1.46 days, 6.88 days, and 3.78 days respectively for the first four data columns in Table C-6.

Summary

For use in the POPDEF model, the weighted effective exit times derived above have been converted to the values shown in Table C-8, where the entries are in hours after detonation. Since trial analyses indicate that the differences in exit times for the two "no water" cases are not significant in terms of casualty production, it is current practice to use 36 and 46 hours as the exit times for those forced out by lack of water in both belowground and aboveground locations (see Table 7 of this report).

Table C-7

POPULATION DISTRIBUTION AMONG CLIMATE GROUPS

CLIMATE GROUP	PERCENT OF POPULATION
A	4%
B	5%
C	29%
D	4%
E	33%
F	12%
G	5%
H	5%
I	1%
J	1%
K	1%

Table C-8

EFFECTIVE EXIT TIMES FOR POPDEF MODEL

Condition	Remedial Movement	No Remedial Movement
No Water/Natural Ventilation	H + 36	H + 46
No Water/Forced Ventilation*	H + 50	H + 53
Water**/Natural Ventilation	H + 91	H + 166
Water/Forced Ventilation	H + 168	H + 216

* Also appropriate for natural ventilation of upper stories of buildings and single-family residences.

** 3.5 gallons of water per person.

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EFFECTIVENESS OF CIVIL DEFENSE SYSTEMS: VOLUMES I AND II
Center for Planning and Research, Inc., Palo Alto, CA
June 1979 414 pp. Contract No. DCPA01-77-C-0223
Work Unit 4114H

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